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THE

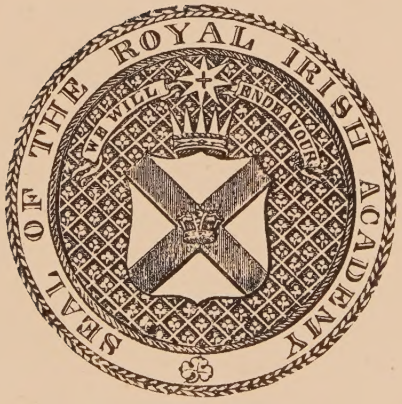
TRANSACTIONS

OF THE

ROYAL IRISH ACADEMY.

VOLUME XXVIII.

SCIENCE.



DUBLIN:

PUBLISHED BY THE ACADEMY,

AT THEIR HOUSE, 19, DAWSON-STREET.

1880–1886.

DUBLIN:

PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY & WELDRICK, PRINTERS TO THE ROYAL IRISH ACADEMY;
AND SOLD AT THE ACADEMY HOUSE; ALSO BY HODGES, FIGGIS, & CO., 104, GRAFTON-STREET, DUBLIN;
AND WILLIAMS & NORGATE, 14, HENRIETTA-STREET, COVENT GARDEN, LONDON.

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TRANSACTIONS

OF THE

ROYAL IRISH ACADEMY.

I.—*On Chemical Equilibrium.* *By* Francis Alexander Tarleton, LL.D., Fellow and Tutor, Trinity College, Dublin.

[Read June 28, 1880.]

In a Paper read before the Academy in November, 1873, and published in the *Transactions*, Vol. xxv., Mr. Jellett stated the condition of equilibrium which must be fulfilled when an acid in solution is in the presence of two bases, more than sufficient in quantity to saturate the whole of the acid.

The equation required for equilibrium was reached by Mr. Jellett by a skilful and elegant combination of mathematical reasoning and experiments, the latter depending on the fact that, in many cases, the plane of polarization of a ray of polarized light undergoes alteration when the ray is transmitted through a liquid column. The amount of the rotation of the plane of polarization indicates the constitution of the liquid.

Mr. Jellett's mode of experimenting is, unfortunately, inapplicable to a combination of inorganic bases and an inorganic acid.

In the following Paper an attempt is made to indicate a method

for ascertaining whether the inorganic bases conform to Mr. Jellett's law of equilibrium.

This method has been applied to two of the best-known inorganic bases. The results appear to confirm Mr. Jellett's law.

It is well known that an equivalent of any given base, combining with an equivalent of acid likewise given, produces a definite amount of heat, and that the separation of an equivalent of given base from one of given acid causes the loss of a definite amount.

Suppose now that there are two bases such that an equivalent of one combining with an acid produces B units of heat, and that the equivalent of the other produces B': then, if the first base decomposes x equivalents of a salt of the second, Bx units of heat are produced, and $B'x$ units lost, $\therefore$ on the whole $(B - B')x$ units of heat appear in the form of a rise of temperature.

If h be the heat developed by mixing a solution of the base with a solution of the salt, we have

$$(B - B')x = h.$$

If now $B - B'$ be known, and h ascertained by experiment, x can be calculated; and hence, by making several experiments, it can be ascertained whether the two bases under consideration and the acid conform to Mr. Jellett's law of equilibrium.

The experiments described in the present Paper were made on the well-known bases potash and ammonia in combination with hydrochloric, nitric, and sulphuric acid.

In order that the experiments should give results of any value in reference to chemical equilibrium, it is requisite that no physical change of state should occur, and also (in order to make satisfactory observations possible) that there should be a sensible difference in the amount of heat produced by the combination of an equivalent of acid with an equivalent of each of the two bases.

Potash and ammonia, within certain limits, fulfil these conditions.

In order to make the experiments, solutions were prepared of known strength of potassium hydrate, and of the chloride, nitrate, and sulphate

of ammonium. A known quantity of the potash solution was placed in a small glass vessel, and an equal quantity of the solution of ammonium salt in another similar vessel. The temperature of each was ascertained by a delicate thermometer, read with a kathetometer. These temperatures having been made nearly or entirely equal, the two solutions were mixed, and the rise of temperature ascertained. The results of the experiments are given in the following Table.

In cases in which the temperatures of the two solutions before mixing were not precisely equal, the mean of the two is given as the temperature before mixing.

p indicates the fraction of a molecule, or equivalent of potassium hydrate, expressed in grammes, contained in each cubic centimetre of the final mixture before chemical action takes place.

a has a similar significance for the salt of ammonium.

In addition to the experiments whose results are exhibited in the Table, several others were made, but, for reasons which will be mentioned, were not considered reliable in reference to the law of chemical equilibrium.

Heat is usually estimated by a number of grammes of water, raised through one degree, or which is very approximately the same, by the rise in temperature of one gramme of water. If, then, the liquids employed in the experiments whose results are given had been pure water at its maximum density, the rise of temperature of each cubic centimetre would have been exactly the amount of heat produced therein; but as it was not pure water at its maximum density, the heat produced was this rise of temperature multiplied by a certain coefficient. It was ascertained, however, partly by direct experiment, that these coefficients are so nearly equal to unity, that within the degree of accuracy to which the experiments on chemical equilibrium are reliable, the rise of temperature of each cubic centimetre may be regarded as the amount of heat which it has received by reason of the chemical action.

Temperatures in Degrees Fahrenheit.

ACIDS.		$p = 0{\cdot}0005$ $a = 0{\cdot}0005$			$p = 0{\cdot}0004$ $a = 0{\cdot}0005$			$p = 0{\cdot}0005$ $a = 0{\cdot}00025$			$p = 0{\cdot}00025$ $a = 0{\cdot}00025$		
		TEMPERATURE.			TEMPERATURE.			TEMPERATURE.			TEMPERATURE.		
		Before Mixing.	After Mixing.	Rise.	Before Mixing.	After Mixing.	Rise.	Before Mixing.	After Mixing.	Rise.	Before Mixing.	After Mixing.	Rise.
HCl	Observed	58·2	59·8	1·6	57·7	59·0	1·3	57·6	58·5	0·9	57·0	57·8	0·8
		..	..	..	..	..	..	48·6	49·6	1·0	57·2	58·0	0·8
		..	..	..	..	..	..	57·4	58·2	0·8	—	—	—
	Mean, . .	..	..	1·6	..	..	..	..	..	0·9	—	—	—
HNO_3	Observed	58·6	60·08	1·48	57·8	58·9	1·1	58·0	58·88	0·88	57·4	58·1	0·7
		57·4	58·7	1·3	57·25	58·4	1·15	57·8	58·6	0·8	—	—	—
		57·3	58·6	1·3	58·42	59·58	1·16	—	—	—	—	—	—
		57·8	59·2	1·4	—	—	—	—	—	—	—	—	—
		58·05	59·55	1·5	—	—	—	—	—	—	—	—	—
	Mean, . .	..	..	1·396	..	..	..	..	..	0·84	—	—	—
H_2SO_4	Observed	58·65	60·0	1·35	58·4	59·4	1·0	48·8	49·5	0·7	59·8	60·45	0·65
		57·6	58·95	1·35	59·5	60·6	1·1	60·1	60·85	0·75	—	—	—
		..	..	..	59·0	60·1	1·1	57·85	58·6	0·75	—	—	—
	Mean, . .	..	..	1·35	..	..	..	..	..	0·733	—	—	—

Law of Equilibrium.

As given by Mr. Jellett, this law is as follows:—The quantity of the first base, uncombined with acid, which is contained in a given volume, multiplied by the quantity of acid in the same volume in combination with the second base, is in a constant ratio to the quantity of the second base uncombined with acid contained in the given volume, multiplied by the quantity of acid in the same volume in combination with the first base.

If the given volume be one cubic centimetre, and a and p have the meanings assigned above, and x be the fraction of a molecule (expressed in grammes) of salt of ammonium, decomposed in one cubic centimetre by the action of the potash, Mr. Jellett's law gives the equation

$$(p - x)(a - x) = kx^2.$$

If, now, one equivalent of potash combining with one of acid produce P units of heat, and one equivalent of ammonium hydrate combining with one of acid produce A units, and if h be the heat developed in each cubic centimetre of the mixture by the chemical action,

$$(P - A)x = h.$$

Let $P - A = \lambda$, then we have the equations

$$(p - x)(a - x) = kx^2, \qquad \lambda x = h.$$

If two different values of h, corresponding to different values of p and a, be observed, we can determine both λ and k as follows:—

From the equations just given, we have

$$\frac{(\lambda a - h)(\lambda p - h)}{h^2} = k;$$

or,

$$\lambda^2 ap - \lambda(a + p)h + h^2 = kh^2;$$

and, similarly,

$$\lambda^2 a'p' - \lambda(a'+p')h' + h'^2 = kh'^2.$$

Assuming

$$B = ap, \qquad C = h(a+p), \qquad D = h^2,$$

we obtain, by eliminating k,

$$\lambda = \frac{CD' - DC'}{BD' - DB'} = \frac{hh'^2(a+p) - h^2h'(a'+p')}{aph'^2 - a'p'h^2}$$

$$= \frac{hh'\{h'(a+p) - h(a'+p')\}}{aph'^2 - a'p'h^2}.$$

If $a = p = p'$, this becomes

$$\lambda = \frac{hh'\{2h'a - h(a+a')\}}{a(ah'^2 - a'h^2)}.$$

Finally, if $a = p = p' = 2a'$,

$$\lambda = \frac{hh'(4h' - 3h)}{a(2h'^2 - h^2)} = \frac{hh'(3h - 4h')}{a(h^2 - 2h'^2)}, \qquad k = \left(\frac{\lambda a - h}{h}\right)^2.$$

If we solve for x the quadratic equation

$$(p-x)(a-x) = kx^2,$$

we obtain

$$x = \frac{a+p \pm \sqrt{(a-p)^2 + 4kap}}{2(1-k)}.$$

Since, from the nature of the case, x is less than either a or p, a negative sign must be attributed to the square root, whence

$$x = \frac{a+p-\sqrt{(a-p)^2+4kap}}{2(1-k)};$$

and,

$$h = \lambda \frac{a+p-\sqrt{(a-p)^2+4kap}}{2(1-k)}.$$

The values of λ and k having been ascertained from two experiments, the value of h can be calculated for any assigned values of a and p, and then compared with the observed value. If they agree, Mr. Jellett's law of equilibrium may be regarded as confirmed.

Another independent confirmation results from comparing the ascertained value of λ with those already given by Favre and Silbermann, Andrews, and Marié Davy and Troost.

The values of λ and k are calculated from observations made when

$$\begin{cases} a = 0{\cdot}0005, \\ p = 0{\cdot}0005, \end{cases} \text{ and } \begin{cases} a = 0{\cdot}00025, \\ p = 0{\cdot}0005. \end{cases}$$

Values of λ *and* k.

KHO in combination with	λ From Observations.	λ Andrews.	λ Favre and Silbermann.	λ Marié Davy and Troost.	$\sqrt{k}$	k
NH_4Cl, ...	3676	3780	3816	3060	0·14875	0·02212
NH_4NO_3, . . .	3612	4320	3302	3240	0·29369	0·08625
$(NH_4)_2SO_4$, . .	2959	3600	2507	2700	0·09621	0·00925

Rise in Temperature in Degrees Fahrenheit, due to the action of KHO *on* NH_4Cl, NH_4NO_3, *and* $(NH_4)_2SO_4$, *when* $a = 0{\cdot}0005$, $p = 0{\cdot}0004$.

	Calculated.	Observed.		
NH_4Cl, ...	1·32	1·3	—	—
NH_4NO_3, . . .	1·22	1·1	1·15	1·16
$(NH_4)_2SO_4$, . .	1·14	1·0	1·1	1·1

It would seem desirable to ascertain, by experiment, whether ammonium hydrate, mixed with a solution of a salt of potassium, gives the fall of temperature required by Mr. Jellett's law, but exact experiments on this point are, unfortunately, not easy of performance.

If the fall of temperature be calculated from Mr. Jellett's equation and the values of λ and k given above, it will be found to be exceedingly small, except the solution of ammonium hydrate be very strong. But, if this solution be very strong, the addition of water to it causes a rise of temperature (doubtless from the absorption of gas), which renders it impossible to observe the fall of temperature due to chemical action.

A somewhat similar difficulty arises when a solution of potash is added to very strong solutions of salts of ammonium. The rise of temperature is not nearly so great as that required by Mr. Jellett's law. At first sight this seems inconsistent with the truth of the law, especially if, as sometimes happens, the rise of temperature diminishes as the strength of the solution increases. Such a result, if due to chemical action, would overthrow the truth of the law; for, from the equation

$$(1-k)x^2 - (a+p)x + ap = 0,$$

we have

$$\frac{dx}{da} = \frac{p-x}{a+p-2(1-k)x};$$

and, as $k < 1$, and $a > x$, $p > x$, $\frac{dx}{da}$ is always positive, and x, and therefore λx, or h, increases with a.

A more careful study of the phenomena leads, however, to the conclusion that there is nothing in the observed facts inconsistent with the law. If water be added to a strong solution of a salt of ammonium (*e.g.* a solution of NH_4Cl, for which, after the addition of the water, $a = 0{\cdot}001$, or for which, before its addition, $a = 0{\cdot}002$), there is a decided fall of temperature. If the addition of a solution of potash caused a fall of temperature equal to that caused by the water, as well as a rise due to chemical action, the latter would be equal to the observed rise, together with the observed fall due to the addition of water. In this way a rise of temperature would be obtained even greater than that required by Mr. Jellett's theory.

The whole investigation, however, in the case of very strong solutions, seems to be fallacious, for the fall of temperature, caused by the addition of water, appears to show that the solution is not really perfect, nor does it seem that we are warranted in assuming that the addition of a solution of potash would (putting aside chemical action) produce the *same* fall of temperature as the addition of an equal volume of water.

It is an immediate consequence of Mr. Jellett's equation, that if a and p be both altered in the same ratio, h is likewise altered in that ratio. This agrees very well with the results of the experiments already given for

$a = 0{\cdot}0005,$ $p = 0{\cdot}0005;$ $\qquad$ $a = 0{\cdot}00025,$ $p = 0{\cdot}00025.$

CORRECTION FOR SPECIFIC HEAT.

In the above results the rise of temperature of each cubic centimetre of the mixture has been taken as equal to the heat developed therein. Theoretically speaking, this is not true. In fact, if n be the number of cubic centimetres in the mixture, c the specific heat of one cubic centimetre, b a constant depending on the vessels employed, t the rise of temperature, and h the heat developed in each cubic centimetre,

$$nh = nct + bt; \quad \text{whence} \quad h = \left(c + \frac{b}{n}\right) t.$$

In the actual experiments $c + \frac{b}{n}$ differed very slightly from unity.

c is easily obtained very approximately as follows :—

Find the specific gravity of each of the solutions employed. If this be s for one solution, a litre weighs $1000\, s\delta$,* subtract the weight of dissolved salt, and the weight of the water is obtained. Let w be the weight of dissolved salt, ω the weight of a molecule in grammes, ν the number of atoms in a molecule, then (the specific heat of 1 gramme of water being unity) the specific heat of salt dissolved in one litre $= \frac{w}{\omega}\frac{\nu}{3} \cdot 18$ q.p., and total specific heat of one litre of solution $= 1000\, s\delta - w + \frac{w}{\omega}\frac{\nu}{3} 18$; whence

$$c = \frac{1000\, s\delta - w + \frac{w}{\omega}\frac{\nu}{3} 18}{1000}.$$

In this way the following results were obtained for solutions containing one equivalent of salt, or potassium hydrate, in litre :—

* δ is density of water, referred to water at 4° C.

Specific Heats of 1 *C.C. of solutions of*

NH_4Cl, . . 0·997079,
NH_4NO_3 . . 1·000538,
$(NH_4)_2SO_4$. 1·009331,
KHO . . . 1·010725.

By a direct addition of warm water to cold water, and an observation of the temperatures, $\frac{b}{n}$ was found to be 0·04157.

If we call c_1 and c_2 the specific heats of 1 cubic centimetre of solution of ammonium salt and of potash, as given above, and c the specific heat of 1 cubic centimetre of the mixture, we have the following formulæ for c, corresponding to different values of a and p in the mixture:—

$a = 0{\cdot}0005, \quad p = 0{\cdot}0005, \quad c = \frac{1}{2}c_1 + \frac{1}{2}c_2;$
$a = 0{\cdot}0005, \quad p = 0{\cdot}0004, \quad c = \frac{1}{2}c_1 + \frac{2}{5}c_2 + \frac{1}{10};$
$a = 0{\cdot}00025, \quad p = 0{\cdot}0005, \quad c = \frac{1}{4}c_1 + \frac{1}{2}c_2 + \frac{1}{4};$
$a = 0{\cdot}00025, \quad p = 0{\cdot}00025, \quad c = \frac{1}{4}c_1 + \frac{1}{4}c_2 + \frac{1}{2};$

whence, if $\mu = c + \frac{b}{n}$, we have the following Table of the values of c and μ for the different salts and strengths of solutions:—

Values of c *and* μ.

KHO with	$a = 0{\cdot}0005$ $p = 0{\cdot}0005$		$a = 0{\cdot}0005$ $p = 0{\cdot}0004$		$a = 0{\cdot}00025$ $p = 0{\cdot}0005$		$a = 0{\cdot}00025$ $p = 0{\cdot}00025$	
	c	μ	c	μ	c	μ	c	μ
NH_4Cl, . . .	1·00340	1·04497	1·00232	1·04389	1·00463	1·04620	1·00195	1·04352
NH_4NO_3, . .	1·00563	1·04720	1·00455	1·04612	1·00549	1·04706	1·00281	1·04438
$(NH_4)_2SO_4$, . .	1·01002	1·05159	1·00895	1·05052	1·00769	1·04926	1·00501	1·04658

The conclusion to be drawn from this Table is, that the specific heat of 1 cubic centimetre of each mixture is sensibly the same as that of 1 cubic centimetre of water.

It is to be observed, further, that the value of $\frac{b}{n}$, obtained by direct experiment, is probably larger than that which holds good for the experiments on chemical equilibrium. For, in the latter, the temperature must be observed when at its maximum, and at this period the temperature of the liquid is probably somewhat higher than that of the vessel which contains it. In the former case, on the other hand, the temperature is not observed till it has ceased to fall more rapidly than it would do under the influence of radiation. When this period is reached, the liquid and the containing vessel are, probably, at the same temperature.

On the whole, then, the rises of temperature in the experiments on Chemical Equilibrium may be considered, without any correction, as the heat developed in each cubic centimetre of the mixture.

II.—*On a New Genus and Species of Sponge with supposed Heteromorphic Zooids.* By Edward Perceval Wright, M.A., M.D., F.L.S., Professor of Botany in the University of Dublin. (With Plate I.)

[Read, November 10th, 1879.]

An account of the different positions held by the group of the Sponges, in the various Systemata Naturæ that have been sketched out, from the time of Aristotle to the present day, would almost serve as a record of the various methods pursued in Biological research during this long period.

Their position in the Animal Kingdom once settled, their proper place in this kingdom was at one time determined by their Habitat; at another time by the Morphology of their External Form; then by their Comparative Morphology and Anatomy; and lastly, by their Embryological details.

However interesting an essay on this subject might be, for my present purpose it is sufficient to go back on its history for only a few years.

Professor Leuckart, in 1848, recognising in the peculiar water vascular system of the Sponges the representative of the coelenteric canal system, placed them in the group of the Coelenterata; but he does not appear to have appealed either to their "ontogeny," or to their "phylogeny," to support this view.

Professor Ernst Haeckel, in 1868, as the result of his profound investigations into the life-history of the Calcispongiæ, laid down the following general proposition, which relates to the whole group of the Sponges, and the greater portion of which he has substantially proved:—

"Die Schwämme sind den Corallen unter allen Organismen am nächsten verwandt. Gewisse Schwämme sind von gewissen Corallen nur

durch den geringeren Grad der histologischen Differenzirung, und namentlich durch den Mangel der Nesselorgane verschieden. Die wesentlichste Organisations-eigenthümlichkeit der Schwämme ist ihr ernährendes Canalsystem, welches dem sogenannten coelenterischen Gefässsystem, oder dem Gastrovascular-Apparat der Coelenteraten, und namentlich der Corallen, sowohl homolog als analog ist. Bei den Schwämmen entstehen, ebenso wie bei den Corallen und wie bei den Coelenteraten überhaupt, alle verschiedenen Theile des Körpers durch Differenzirung aus zwei ursprünglichen, einfachen Bildungshäuten oder Keimblättern, dem Entoderm und dem Ectoderm. Diese beiden Blätter entstehen durch Differenzirung aus den anfangs gleichartigen Zellen, welche (aus der Eifurchung hervorgegangen) den kugeligen Leib des flimmernden Embryo oder der primitiven Larve (Planula) zusammensetzen. Aus dem inneren oder vegetativen Keimblatt, dem *Entoderm*, entsteht das ernährende Epithelium des Canalsystems und die Fortpflanzungsorgane. Aus dem äusseren oder animalen Keimblatt, dem *Ectoderm*, entstehen alle übrigen Theile." *

This kinship of the Sponges to the Corals, while it assists us to an understanding of a common ancestry for both, is still not an intimately close one, and notable differences between them exist. One of these, which even at once strikes the casual observer of their external forms, is an absence of Heteromorphism. In the corals there is often a great diversity of form among the zooids, which difference in form is also accompanied by a corresponding diversity in the functional work done by these (Polymorphismus of Haeckel). It is true, indeed, that in the sponges there is a marked tendency to an extreme changeableness of form, without any difference in function (Polymorphosis of Haeckel).

A social sponge stock (cormus) will often consist of many personæ. These may, and often do, present a very great difference in the shape of their external forms; still these personæ will all have the same general functions; and I am not aware that any differentiation in these has been noticed, unless, indeed, certain bud-like processes, alluded to by Bowerbank and Oscar Schmidt, can be regarded as specialized personæ.

* "Jenaische Zeitschrift für Medicin und Naturwissenschaft," Bd. v. 5. 212. These views have been slightly modified since (1879).

In *Guancha blanca* of Macleay there is a very wonderful diversity of form among the personæ of one and the same cormus, and yet there does not appear to be the least tendency to any polymorphism; and the same may be said of *Sycometra compressa* of Haeckel. Indeed it would almost seem as if this extraordinary instability of the contour of the body in sponges is directly antagonistic to any such true and physiological division of labour among their zooids as exists, for example, among the Siphonophora.

If this be so, a sponge form, even exhibiting in a feeble way the first beginnings of such a division among the personæ of its cormus, will possibly be regarded with interest. When I detached the small mass below described from the edge of a coral reef, I thought I had gathered an Alcyonarian. A little examination showed it to be a sponge colony, which might possibly be included as a species in the genus Tethya (O. Sdt.), but which differs from any species of this genus sufficiently to justify me in forming of it a new genus.

Alemo* (new genus).

Sponge mass, presenting a mammillated appearance; semi-globular in shape (Plate I., fig. 1); basal portion adherent. The mammillary projections, when fully developed, of two sorts, arranged in pairs, and these in indistinct whorls (Plate I., fig. 2). In the one set of projections (personæ) the nipple-like portion seems to be, at a slight distance from the surface of the general sponge mass, slightly contracted; it then becomes a little fuller, and again gradually contracts, ending in a slightly enlarged apex, in which is an osculum (Plate I., fig. 3). In the other set of projections the form is that of a long stalk, ending in an irregular fan-like process, which seems to act as a protecting organ to the osculum-bearing persona (Plate I., fig. 3). While those having oscula were more or less rigid, the shield-like processes were extremely flexible. In the former a number of fusiform acerate spicules formed a fringe round their base of insertion. Such spicules were generally absent in the latter, but the base of the stalk was studded with stellate spicules (Plate I., fig. 8).

* ἀλήμων, a wanderer.

Alemo Seychellensis (spec. nov.)

The sponge colony was about two and a-half centimetres in both diameters, and nearly the same in height. In colour it was a light ruddy brown.

The spicules were all siliceous, and, using the terminology of Bowerbank, which the illustrations will enable the reader to understand, may be described as follows:—The general mass was permeated with—(1). Spicules of a fusiform-acerate type, of large size (Plate I., fig. 6 *a*); these were also to be found in both forms of personæ; thick bundles of them forming the stalk and the expanded portion of the sheltering forms; they were intermixed with others of the same type, but of less than a third their size (Plate I., fig. 6 *b*), which were also protruded from the surface of the general sponge mass, and formed spicular masses around the base of the projections and around the oscula. (2). Spicules of a stellate type, with body large, rays small, were everywhere abundant. Those of a sub-spherical stellate form, with acutely conical radii (Plate I., fig. 4), formed a cortical layer over the general sponge mass. At the basal portion of both sorts of projections these were of the form represented in fig. 8 (Plate I.) Along the stalk-like portion of the sheltering personæ the stellate spicules were wonderfully small, as figured on the Plate (fig. 6 *c*). (3). Stellate spicules, with almost no central portion (body), and rays long, were also met with. Of these, one form, somewhat of Bowerbank's alternate-stellate type, but with the rays often bifid, were found throughout the general sponge mass (Plate I., fig. 5). The others, the cylindro-stellate of Bowerbank, were scattered through the personæ, and had blunted radii (Plate I., fig. 7). In both these forms the number of the radii varied much.

Habitat—The inner margin of a coral reef which fringes the south-eastern shore of Mahé, one of the Seychelles group, August, 1867.

The figures accompanying this Paper were drawn under my superintendence by Mr. Lens Aldous in March, 1870. The figures 1, 2, and 3, Plate I., were drawn from the specimen collected by myself. The drawings of the spicules were from my own mountings, and the above Paper was prepared by me at the time (1870) to form part of a volume on

the Natural History of the Seychelles. Circumstances hindered the publication; but in a note from Professor Haeckel, received in May, 1879, he stated, on referring to the drawings and manuscript, that having looked over both with much interest, he fancied this was still the first instance of a division of labour among the sponges. I therefore venture to lay it now before the Academy.

NOTE ADDED IN THE PRESS.

On Gemmation in Sponges.

Since reading the above Paper before the Academy, I have received from my friend, Professor Emil Selenka, of Erlangen, a copy of his account* of *Tethya maza*, and a few days afterwards I obtained a copy of C. Merejkowsky's "Études sur les Éponges de la mer Blanche,"† and a perusal of these suggests the rather startling idea that in the species described above, the stalked portions, destitute of oscula, may after all be products of a process of Gemmation rather than a form of Heteromorphism. Even more, if one looks at the illustration given by Selenka of *T. maza* (l.c. Taf. xxviii., figures 9 and 10), there will be found to exist a very close general resemblance between these "buds" of *T. maza* and my stalked personæ; and one has not to draw much on imagination to detect a likeness also between these latter and the globular buds figured by Merejkowsky (l.c. Pl. I., figure 12), as found in *Rinalda arctica*.

The subject of gemmation in sponges has not as yet been thoroughly investigated. J. H. Stewart seems to have been the first to notice the phenomenon; and Dr. Bowerbank showed me some of Stewart's specimens, from one of which, figure 342 of volume i. of Bowerbank's *British Sponges*,

* Ueber einen Kieselschwamm von achtstrahligem Bau und über Entwicklung der Schwammknospen (Separat-Abdruck aus "Zeitschrift f. wissensch. Zoologie," Bd. xxxiii. 3).

† "Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg," vii^{e} série. tom. xxvi. No. 7.

is drawn. This occurred curiously enough in *Tethya lyncurium;* but, as well as I can remember, the sarcodic masses (external gemmules of Bowerbank) were thrown off from the main body of the sarcode towards its base, and there did not appear to be any localized function of budding.

In *Tethya maza* (Selenka), a species found by its describer in the Bay of Rio Janeiro during 1877, the formation of buds was most abundant, and seemed to take place from all portions of the sponge mass. The spicules of this sponge differ in some respects from those in the species I describe, those represented in figure 5, Plate I., being apparently absent. The budding takes place as follows:—Right round about each of the 200–400 bundles of spicules the stellate or spindle-shaped cells undergo a metamorphosis, changing into small, large-nucleated cells, adding to their number at the same time, to such an extent as to force out the adjoining subdermal and subcortical hollow spaces (Hohlräume). Cotemporaneously with this, a large number of ciliated chambers, like clusters of grapes, make their appearance in the inner parenchyma of the sponge mass. During the bud growth the number of these increases, and when the bud has gradually made its way out through the mother-cortex, the canal-system of the ciliated chambers becomes cut off from that of the mother-sponge.

Longitudinal and transverse sections of buds, at this stage of their development, show that they chiefly consist of homogeneous mesoderm cells (cortical cells of the mother-sponge), but that the inner portion of each is compactly filled with a continuous system of ciliated chambers, and their closely connected canal system. When the bud gets beyond the outer surface of the mother-sponge it glides outwards on a spicular bundle, so that by the time it becomes ready for falling off it has a stalked appearance. At this stage one can easily see (especially after silver-staining) an outer layer of flattened epithelial cells. All those mesoderm cells which surround the subcortical cavities form a kind of endothelium. Siliceous spicules often make their appearance in the still unprotruded bud. As long as the bud is at all attached to the mother-sponge, even when this attachment is little more than through a bundle of the needle-like spicules, there is no trace of the osculum nor of the subdermal cavities.*

* *Loc. cit.*, p. 173.

The bud-development of the other most remarkable species described by Selenka, *Tetilla radiata*, is also much of the same type.

In *Rinalda arctica*, Merejkowsky's new species, found in the White Sea, the budding takes place after a very peculiar type, thus described :— "Ici, de même que dans la *Rinalda uberrima* O. S. la surface du corps donne naissance à un grand nombre de papilles en forme de cône, mais avec cette différence que dans la *Rinalda arctica* les cônes sont placés avec plus d'ordre et ont une forme plus élégante et plus élancée, plus fine à leur extrémité, où du reste on ne peut apercevoir aucun orifice, aucun oscule ; en général les cônes sont un peu retrécis à leur base de sorte que la partie la plus grosse se trouve au milieu (Plate I., fig. 8 et 9). La grandeur des cônes atteint ordinairement 5–8 mm. de longueur, ils sont plus petits près du bord de l'éponge et atteignent leur maximum de longueur au milieu. Chaque individu adulte est muni de 1 à 5 orifices ou oscules (Plate I., fig. 7 osc.), en forme de papilles cylindriques, un peu plus longues que les cônes, au reste n'en différant que par leur forme et par une assez large ouverture circulaire placée à l'extrémité du tube (Plate I., fig. 11). Les cônes de même que les cylindres ou osculums sont d'une couleur jaune, variant d'une nuance claire à une nuance presque orange comme c'est le cas par exemple dans l'individu le plus grand que j'ai trouvé (Plate I., fig. 9) ; ni les cônes, ni les tubes cylindriques n'ont jamais leur surface recouverte de cette couche de sable et de vase, qui rend la surface du corps brune."*

Not only is the marked regularity of the cone-like papillæ a noteworthy feature in this species, but the facts that these give off time after time from their tips the real gemmæ, being thus, as it were, bud-producing personæ, and that these latter have thereby a function of their own, point to a kinship with the species from the Seychelles.

I am indebted to the kindness of my friend, Selenka, for an excellent specimen of his *Tethya maza*, and I should have liked, with the light thus thrown on my new form, to have closely compared the two ; but unfortunately my specimen, with other sponges not so precious in my eyes, went

* *Loc. cit.*, p. 5.

in 1876 "nach Weimar," and this in the very literal sense, and it has not found its way back since.

To those who know the many years of his life (over sixty) that were devoted to the drawing and study of sponges by that excellent artist, Lens Aldous, it is scarcely necessary to say a word as to the accuracy of the drawings accompanying this Paper. Whether further investigation will justify my making of the form here figured a new genus or species remains to be seen. That it is an instance of Heteromorphism in the group of the sponges would not be negatived even if a wrong function be ascribed to the shield-like personæ.

EXPLANATION OF PLATE I.

Fig. 1. Alemo Seychellensis, sponge mass, natural size.
,, 2. Portion of Sponge, magnified.
,, 3. The two forms of Personæ, greatly magnified.
,, 4 to 8. Spicules, variously magnified.

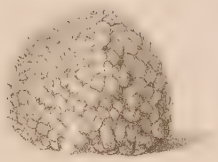


Fig. 1.

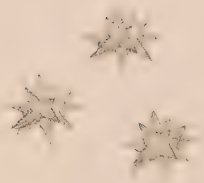


Fig 8

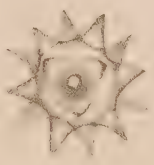


Fig. 4

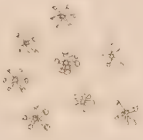


Fig. 7.

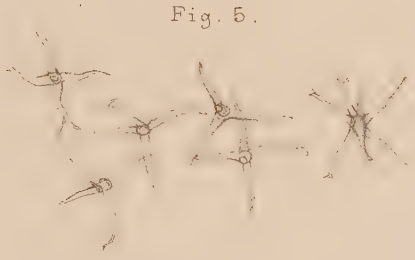


Fig. 5.

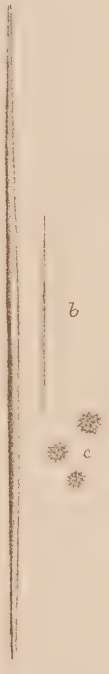


Fig 6.

Fig 3

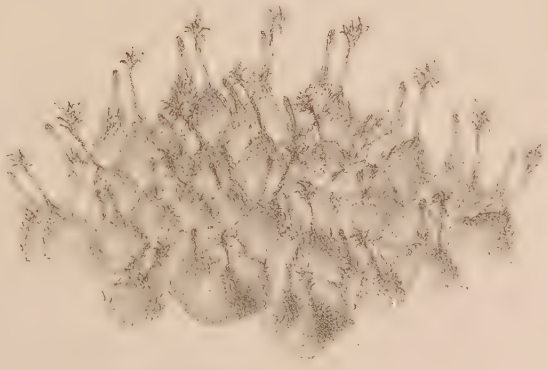


Fig. 2.

III.—*On Blodgettia confervoïdes of Harvey, forming a new Genus and Species of Fungi.* By Edward Perceval Wright, M.A., M.D., F.L.S., Professor of Botany in the University of Dublin. (With Plate II.)

[Read, November 10, 1879.]

The genus Blodgettia was described by the late Professor W. H. Harvey as a genus of green algæ (Chlorospermeæ), belonging to the order Valoniaceæ. As this description is not very easily accessible, and yet is necessary for the understanding of the following remarks, I quote it in full:—

"Blodgettia confervoïdes (Harv.)

"Hab. At Key West, on rocks near low-water mark. *Dr. Wurdeman, W. H. H., Prof. Tuomey.* (v. v.)

"*Fronds* filamentous, densely tufted; the tufts spreading extensively, from an inch to an inch and half in height, very dense, pulvinate and fastigiate. *Filaments* rigid, not collapsing when removed from the water, about as thick as a hog's bristle, sparingly branched, decumbent at base, then ascending, and the tips erect. The main divisions and primary branches are very patent, either arching backwards or quite recurved. They are destitute of branches along their lower or outer side, and more or less furnished with unilateral ramifications on the upper; generally with a long excurrent point destitute of ramuli. Often the filament has but a single series of simple secund ramuli; but in luxuriant specimens there is a second series of similar secund ramuli. *Articulations* variable in length, dark coloured, with opaque dissepiments, and not collapsing when dry,

contracted at the nodes, three to six times as long as broad; the terminal cell always very much longer than the rest, and frequently 10–12 times as long as its diameter. *Apices* very blunt. The articulations are filled with dense, viscid endochrome full of large green granules, and frequently containing also prismatical crystals. The membranous cell-wall is divisible into three or more separate membranes, one concentrically placed within the other. The outer are hyaline without obvious structure; but the inner one is reticulated with very slender nerve-like fibres, which run longitudinally through the membrane parallel to each other, and are connected by oblique crossbars; so that the surface is divided into narrow, pointed areolæ. The *spores* are seriated in moniliform strings, four or more in each string, and attached to short free veinlets which issue from the veins of the inner cell-wall. The *colour* when recent is a very dark green; when dry it becomes more olivaceous. The substance is very firm, and the plant imperfectly adheres to paper in drying." *

Accompanying this description there is a representation of the new genus, giving a sketch of the growing plant, of a twig magnified, of the upper portion of one of the terminal cells, of the innermost cell-coat traversed by slender fibres bearing strings of spores (?), and of one of the moniliform strings apart. These latter, it may be remarked, are coloured on the Plate green, though they are nowhere directly referred to in the text as being of this colour.

This genus has long been a puzzle to all botanists working at the marine algæ. Still it has been generally accepted, and even my friend Professor Farlow, in his important "List of the Marine Algæ of the United States," published in 1875,† writes about it in the following somewhat doubtful terms:—"This plant is certainly worthy of a most careful study. The figure of Harvey is most extraordinary, and if correct, this plant deserves at least to be the type of a new order. As Mr. Bornet suggests, however, the spores (?) are parasitic unicellular algæ. The Blodgettia itself is probably nothing more than a Cladophora, nearly related to *Cladophora prolifera*."

* Nereis Boreali-Americana—Smithsonian Contributions to Knowledge, 1858.

† Proceedings of the American Academy of Arts and Sciences, vol. x. p. 378.

In the winter of 1875–76 I was engaged in arranging the green algæ in the Herbarium of Trinity College, Dublin, and I found some specimens of *Cladophora caespitosa* which had been collected by Dr. Klein in Bermuda. These, on examination, showed the same peculiar appearances as figured by Harvey under the name *Blodgettia confervoïdes*. Although the specimens were examined after having been in a dried state for many years, it was at once apparent that the so-called moniliform spores had nothing in common with the algæ within whose green cells they were growing; that these spores were not green; and that they took their origin from hyphæ threads, which constituted the nerve-like fibres of Harvey. I exhibited specimens demonstrating this at the meeting of the Dublin Microscopical Club for March, 1876,* referring at the time to Professor Farlow's statement of Dr. Bornet's opinion, in accepting which as the probable explanation of the facts, I concluded that the phrase "unicellular parasitic algæ" was meant to stand as equivalent to a "parasitic thallophyte."

Anxious to investigate this strange parasite in as fresh a state as possible, I wrote to Professor Farlow, asking him to endeavour to get me some recent morsels of the Cladophora, which served as its host, preserved in fluid. This he most kindly did for me, and a good supply reached me early in the spring of 1879. On an examination of these, my first suspicions were confirmed, and I exhibited a series of freshly-mounted specimens at the meeting of the Dublin Microscopical Club for April, 1879.† By a fortunate coincidence, on the very day of the meeting I received the following memorandum from my friend Dr. Bornet, whose attention had been attracted to the published note already referred to above:—

"Lors de son séjour à Antibes, en 1874, M. le Dr. Farlow eut l'obligeance de me donner un exemplaire de *Blodgettia confervoïdes*, plante singulière dont la structure est tout à fait celle d'un Cladophora, mais dont la membrane interne, selon Harvey (Nereis Boreali-Americana III., p. 47), est parcourue par des nervures parallèles, longitudinales, anastomosées,

* Quarterly Journal of Microscopical Science, July, 1876, p. 342.

† *Ibid.*, January, 1880, p. 111.

desquelles naissent des ramules *libres*, terminés par des chapelets de spores.

"Soumis immédiatement à l'examen, le *Blodgettia* ne s'est pas présenté tout à fait comme le figure et le décrit Harvey. D'abord, toutes les cellules ne montrent pas le réseau caractéristique du genre. Beaucoup en sont dépourvues. Dans les rameaux latéraux ainsi que dans les cellules terminales, le réseau n'occupe souvent que la partie inférieure de l'article. Ensuite, sous un grossissement suffisant, les pretendues nervures ont tout à fait l'aspect et la structure de filaments mycéliens. Ils sont cloisonnés, émettent de distance en distance des branches qui s'anastomosent avec les filaments voisins, ou qui se renflent de manière à constituer les chapelets de cellules que Harvey considère comme des spores.

"Les filaments rampent dans l'épaisseur de la membrane lamelleuse du *Cladophora*. Les spores font saillie à la face interne, mais ne sont pas libres.

"Harvey figure les spores avec une couleur verte. Sur le sec elles n'offrent aucune trace de cette coloration; la matière granuleuse qu'elles renferment est jaunâtre ou rosée. Par l'iode, et après l'action de la potasse caustique, la membrane se teint en bleu pâle. Le contenu cellulaire devient brun. Je n'ai pas observé de mycélium, ni de spores dans les cloisons.

"Selon toute apparence, le Blodgettia est un Cladophora du groupe des Œgagropila (*Clad. caespitosa*, Harv.), dans laquel s'est développée une production parasite. Mais quelle est la réelle nature de cette production? C'est ce que je n'oserais décider sur des échantillons d'herbier. Aussi n'aurais-je rien publié à ce sujet si je n'avais à rectifier une note de M. le Dr. Farlow qui m'a attribué une opinion que je n'ai jamais eue (*Proc. Amer. Acad. of Arts and Sciences*, vol. x., 1875, p. 378; *Journ. of the Dublin Micr. Club*, vol. iii., 1876, p. 133). Jamais je n'ai cru ni pu croire que les spores fussent des Algues *unicellulaires* parasites. Mais dès le premier moment, j'ai pensé que le Blodgettia était un nouvel et curieux exemple d'un développement parasitaire, et que le genre Blodgettia n'existe probablement pas dans le sens où Harvey l'a établi."

It is thus evident that the mysterious plant known as *Blodgettia con-*

fervoïdes of Harvey has no existence, and that the diagnosis is framed partly on an algal and partly on a fungal form. The algal form may be relegated to the species whose external facies the genus Blodgettia, according to Harvey, simulated, and the fungal form is entitled to an independent name and a description.

To use an old name in a new sense is, for the most part, very objectionable; but in the present case I venture to think it allowable. Despite Harvey's diagnosis, the idea of the genus Blodgettia was to a very great extent associated in the minds of all who read that diagnosis with the "strings of spores"; and now I would in a new sense apply to the plant which forms the hyphæ and those strings of one-celled joints the name Blodgettia, and associate with this the name of him who gave the first hint as to the true position of the plant, Dr. E. Bornet.

Blodgettia (gen. nov.)

Conidia scarcely cylindrical; moniliform, borne on short peduncles. Hyphæ at first free, then occasionally inosculating; only the older portions giving origin to conidia.

Blodgettia Bornetii (sp. nov.)

Conidia two to five in number; the central ones larger than those at base or apex of the string; of a dark-brown or brownish-red tinge.

The only form at present known of this fungus is that figured (Plate II., figs. 1, 4). The hyphæ are very numerous, and occasionally inosculating. They chiefly ramify along the inner cell-wall of the older or first-formed cells of the twigs of the Cladophora, getting often underneath the secondary layers of the cell-wall, and making their way from cell to cell; generally for this purpose coursing along the transverse cell-wall and penetrating into the adjoining cell at the central or weakest portion of this wall. Fresh layers of cell-wall will sometimes be seen to be deposited after the hyphæ have been well developed on the innermost existing layer, and this will give the appearance of these layers being permeated with the fungus.

The terminal portion of the hyphæ would seem to be destitute of the

conidia-like bodies (spores), and these would seem to be irregularly found here and there on the older portions of the hyphæ. Even in the very oldest portions of the Cladophora cells the hyphæ do not appear to become felted. Much further information will be necessary in order to determine the affinity of this form, which is especially interesting from its parasitism in a *marine* green alga.

EXPLANATION OF PLATE.

Plate II.

Fig. 1. *Blodgettia Bornetii*, greatly magnified, showing hyphæ and conidia (after a drawing by Dr. E. Bornet).

,, 2. Cells of *Cladophora caespitosa*, with *B. Bornetii*, permeating the cells (after a drawing by Dr. E. Bornet), greatly magnified.

,, 3. Upper portion of an old cell of *Cladophora caespitosa*, one of Professor Farlow's specimens, with *B. Bornetii*—optical section, greatly magnified.

,, 4. *Cladophora caespitosa* (after Harvey).

IV.—*On a New Genus and Species of Unicellular Algæ, living on the Filaments of Rhizoclonium Casparyi.* By Edward Perceval Wright, M.A., M.D., F.L.S., &c., Professor of Botany in the University of Dublin. (With Plate II.)

[Read November 10, 1879.]

The genus Rhizoclonium was established by Kützing for a number of non-gelatinous confervoid algæ, with short and root-like branches, the cells pretty uniform in diameter, and the root-like branches put forth at very irregular distances and from the central portion of the cell; the species would seem to occur both on land, in fresh water, and in the sea. So far as I know, no form of asexual or sexual reproduction has been found, unless, indeed, the fact has been noted that when a filament gets broken into few or many fragments, each of these grows anew into long, slender, often tortuous filaments, which filaments in some species will twist in and around other plants, and look like delicate morsels of green flock silk. Some specimens gathered at Howth during the month of May, 1878, attracted my attention by having a number of fruit-like projections scattered here and there over their filaments; but on a closer examination with the microscope I found that these, instead of being as I had for a moment thought, fruits, were really independent organisms which I believe to be undescribed.

They were one-celled, the basal or attached portion of the cell being in some cases very slightly stipulate, but in others quite sessile. The outline of the apical or free portion of the cell varied with age. In the very young condition it was nearly spherical; as it matured it became either slightly

flattened, so as to give a fig-shape to the cell, or sometimes it became irregularly pentagonal. In the early stages the bright-green chlorophyllaceous contents completely filled the cell. Later on a second cellulose membrane seemed to be formed, and within this the protoplasmic contents divided into numerous biciliated zoospores. These escaped through the apical portion of the cell, leaving as they escaped the somewhat tough coats of cellulose of a faint straw tinge and irregularly burst through.

But one "crop" of the Rhizoclonium was met with in 1878; and although watched for in 1879, the species did not make an appearance in my collecting district, and so I was unable to observe further the green unicellular epiphyte. It seems to me, however, worthy of being placed on record, though it is not easy to be sure of its affinities.

Alex. Braun long ago described several very interesting forms of unicellular algæ living on filamentous algæ.* Of these the species of the genera Hydrocytium and Characium are to be found living on fresh-water plants. There is a good deal of resemblance between the epiphyte of Rhizoclonium and some of these, for example, *Hydrocytium acuminatum* (Tab. II. A), and *Characium Sieboldii* (Tab. III. A); but so far as Braun's description and my experience go, there is never formed in either of these genera an inner investing coat of cellulose, within which again the spores are formed.

In the genus Codiolum, also described by Braun,† there is, however, a complete separating off of the upper green portion of the protoplasm from that in the lower portion (the stock-like portion), and around this a separate layer of cellulose is formed. Within this the zoospores are developed.

In Hydrocytium and Characium, again, the zoospores escape (so far as I know, invariably) by a rupture of the mother cell in a lateral direction; whereas in the plant under description the eruption of the spores was by means of an apical slit. These may seem small points of detail to some, but they appear to be of importance as indicating the affinities of this plant rather to Codiolum, with, perhaps, the same amount of distinction between it and Codiolum that there would appear to be between Hydro-

* Algarum Unicellularum genera nova et minus cognita: Lipsiæ, 1855.

† *Loc. cit.*, p. 19, Plate I.

cytium and Characium. Eaton and Farlow place *Codiolum gregarium* under Botrydium, but do not state their reasons for this.

Dr. Hermann, in his "Ueber die bei Neudamm aufgefundenen Arten des Genus Characium,"* describes thirteen species, all found on fresh-water plants, and most of them of very minute size. One of these, *Characium eurypus*, is a very interesting form, the figure of which in some respects resembles the plant I describe, but, unfortunately, the description of the species gives but little particulars of its dimensions, and nothing was ascertained as to the formation of its zoospores. Although, however, the number of species of the genera Characium and Hydrocytium is now numerous, none of the species have been found on plants living in salt water. Dr. Hermann hints that it is probable that some of the species give origin only to a single zoospore. I cannot find any confirmation of this in recent literature, nor does the phenomenon occur in the plant living on Rhizoclonium.

Kützing, in his "Tabulæ Phycologicæ," figures and describes *Rhizoclonium pannosum*, from the North Sea, with curious inflated cells projecting, like little spheres, from below one of the transverse filaments—"Fäden mit einer aus Schleimkörnern bestehenden Seitenkugel (d)";† but these do not appear to be the epiphyte which I am describing.

Sykidion‡ dyeri (n. g. et sp.)

Vegetative stage consists of a unicellular organism, with a tough cell-wall, attached by its narrow basal portion to the filaments of *Rhizoclonium Casparyi* (?). It presents somewhat the shape of a little fig. The cell contents are of a bright grass-green colour. When the cell attains its full dimensions, a second cellulose layer is formed, and shortly afterwards the protoplasmic contents divide into a number of separate masses, which escape by the rupture of the apical portion of the two cell-walls in the form of biciliated green zoospores. On their escape, the walls of the

* Rabenhorst's Beiträge zur näheren Kenntniss und Verbreitung der Algen'—Heft i. p. 23 : 1863.

† *Loc. cit.*, Band. iii., Tab. 70, fig. 1.

‡ *συκίδιον*, a little fig.

mother plants scarcely, if at all, alter in shape, remaining persistent. These are then of pale straw-colour, and might be mistaken for the empty lorica of an infusorian.

My friend William Archer, F.R.S., tells me that he has found a form somewhat resembling the one just described in fresh-water gatherings, living on the filaments of a species of Mongeotia.

I have called the species after Thiselton Dyer, M.A., F.R.S., some time Professor of Botany in the Royal College of Science, Dublin, and now Assistant Director of the Royal Gardens, Kew.

EXPLANATION OF PLATE.

Plate II.

Fig. 5.—A branching filament of *Rhizoclonium Casparyi* (?), with five specimens of *Sykidion Dyeri*, in various stages of growth, and four empty cells of the same.

Horace Knight, lith.

West, Newman & Co. imp.

V.—*On the Periods of the First Class of Hyper-Elliptic Integrals.* By William R. Westropp Roberts, M.A.

[Read, November 8th, 1880.]

I propose to investigate the Periods of Hyper-Elliptic Integrals by a method analogous to that which has been adopted by Schloëmilch for the determination of the periods of elliptic functions. By this method I determine the periodicity of hyper-elliptic integrals without integrating the system of equations:—

$$\begin{cases} F(u_1)\,du_1 + F(u_2)\,du_2 + F(u_3)\,du_3 = 0; \\ u_1 F(u_1)\,du_1 + u_2 F(u_2)\,du_2 + u_3 F(u_3)\,du_3 = 0, \end{cases}$$

where

$$F(u) \equiv \frac{1}{\sqrt{u(1-u)(1-k_1^2u)(1-k_2^2u)(1-k_3^2u)}} \equiv \frac{1}{\sqrt{U}}.$$

By assuming $u = z^2$ these equations are transformed into the following:—

$$\begin{cases} f(z_1)dz_1 + f(z_2)\,dz_2 + f(z_3)\,dz_3 = 0; \\ z_1^2 f(z_1)\,dz_1 + z_2^2 f(z_2)\,dz_2 + z_3^2 f(z_3)\,dz_3 = 0, \end{cases}$$

where

$$f(z) \equiv \frac{1}{\sqrt{(1-z^2)(1-k_1^2z^2)(1-k_2^2z^2)(1-k_3^2z^2)}} \equiv \frac{1}{\sqrt{Z}};$$

and, if $z = \sin\phi$, are further transformed into

$$\frac{d\phi_1}{\Delta(\phi_1)} + \frac{d\phi_2}{\Delta(\phi_2)} + \frac{d\phi_3}{\Delta(\phi_3)} = 0;$$

$$\frac{\sin^2\phi_1 d\phi_1}{\Delta(\phi_1)} + \frac{\sin^2\phi_2 d\phi_2}{\Delta(\phi_2)} + \frac{\sin^2\phi_3 d\phi_3}{\Delta(\phi_3)} = 0.$$

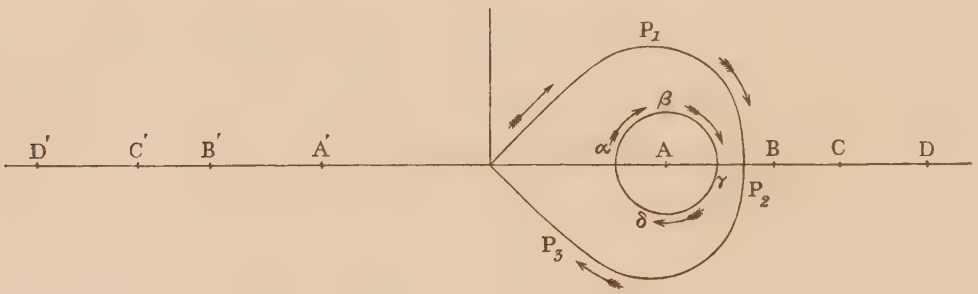
Let us consider the integral

$$\int_0^z f(z)\,dz,$$

in which we suppose z to be a complex variable, and let us examine the different values of the integral for different routes of integration, and let $[f(z)]$ denote the absolute value of $f(z)$. We shall suppose that k_1, k_2, k_3, are all real, less than unity, and arranged in ascending order of magnitude: we see that $f(z)$ has eight singular points

$$z = \pm 1, \qquad z = \pm \frac{1}{k_3}, \qquad z = \pm \frac{1}{k_2}, \qquad z = \pm \frac{1}{k_1},$$

which we shall call A, A'; B, B'; C, C'; D, D'; situated on the axis of x, for which $f(z)$ is infinite. Any two of these points, such as A and A', are then at equal distances from the origin O. Now the revolution of z round any one of these points gives a change of sign to $f(z)$; they are consequently points of ramification. (Verzweigungspunkte.)



Now, suppose that z describes a closed curve $OP_1\,P_2\,P_3\,O$ surrounding the point A, and let $I(A)$ be the corresponding value of $\int f(z)dz$; we shall have then, since we may substitute for the route $OP_1\,P_2\,P_3\,O$ the route $O\alpha\,.\,\alpha\beta\gamma\delta\alpha\,.\,\alpha O$, $\alpha\beta\gamma\delta$ being a circle of radius r, whose centre is at A,

$$I(A) = I(O\alpha) + I(\alpha\beta\gamma\delta\alpha) + I(\alpha O).$$

To evaluate these integrals we put $z = 1 - r$ in the first and third, and $z = 1 - re^{i\theta}$ in the second; then, since $f(z)$ changes sign after z describes the circle $a\beta\gamma\delta a$, we find

$$I(A) = \int_0^{1-r} f(z)\,dz - ir\int_0^{2\pi} f(1 - re^{i\theta})\,e^{i\theta}\,d\theta - \int_{1-r}^{0} f(z)\,dz.$$

The integral relative to the circle is easily seen to vanish when r is zero, so that the value of $I(A)$ reduces to

$$I(A) = \int_0^1 f(z)dz - \int_1^0 f(z)dz = 2\int_0^1 f(z)dz.$$

The function $f(z)$ has now returned to 0 with a negative sign, so that for a second revolution round A the value of the integral will be $-2\int_0^1 f(z)\,dz$. If, with Schloëmilch, we denote by $I_n(A)$, $I_n(A')$ the values of the integral after n revolutions round A and A' respectively, $f(z)$ being supposed positive at the commencement of the circuits, we shall have the following system of equations, since the values of the integral round the remaining points of ramification follow by symmetry :—

$$\left.\begin{aligned}
I_{2n+1}(A) &= 2\int_0^1 f(z)dz, & I_{2n+1}(A') &= -2\int_0^1 f(z)dz,\\
I_{2n+1}(B) &= 2\int_0^{\frac{1}{k_3}} f(z)dz, & I_{2n+1}(B') &= -2\int_0^{\frac{1}{k_3}} f(z)\,dz,\\
I_{2n+1}(C) &= 2\int_0^{\frac{1}{k_2}} f(z)dz, & I_{2n+1}(C') &= -2\int_0^{\frac{1}{k_2}} f(z)\,dz,\\
I_{2n+1}(D) &= 2\int_0^{\frac{1}{k_1}} f(z)\,dz, & I_{2n+1}(D') &= -2\int_0^{\frac{1}{k_1}} f(z)dz,
\end{aligned}\right\} \qquad (2)$$

$f(z)$ returning to 0 with a negative sign.

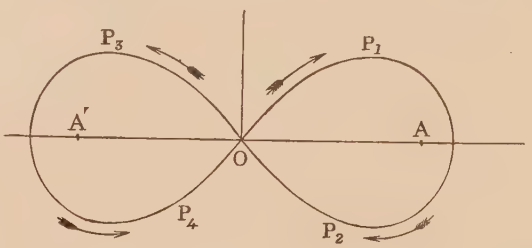
$$\left.\begin{aligned}
I_{2n}(A) = I_{2n}(B) = I_{2n}(C) = I_{2n}(D) = 0,\\
I_{2n}(A') = I_{2n}(B') = I_{2n}(C') = I_{2n}(D') = 0,
\end{aligned}\right\} \qquad (3)$$

$f(z)$ returning to 0 with a positive sign.

If z moves on a closed curve, as in the figure, surrounding both A and A', then

$$I(A) + I(A') = 4\int_0^1 f(z)dz; \tag{4}$$

for, after z has described the curve surrounding A, $f(z)$ arrives at O with, and therefore commences the circuit of A' with a negative sign. $I(A')$ is in



this case equal to $+2\int_0^1 f(z)dz$; and obviously if z describe this curve a times, we must have

$$I_a(A) + I_a(A') = 4a\int_0^1 f(z)\,dz. \tag{5}$$

If we now consider the integral $\int_0^z z^2 f(z)\,dz$, we see that the function $z^2 f(z)$ has the same points of ramification as the function $f(z)$; so that if we denote by $I'(A)$, $I'(B)$, $I'(C)$, $I'(D)$, what $I(A)$, $I(B)$, $I(C)$, and $I(D)$ become respectively when we substitute $z^2 f(z)$ for $f(z)$, we shall have, by a process of reasoning precisely similar to that which we employed for the determination of the latter functions—

$$\left.\begin{aligned}
I'_{2n+1}(A) &= 2\int_0^1 z^2 f(z)dz, & I'_{2n+1}(A') &= -2\int_0^1 z^2 f(z)dz,\\
I'_{2n+1}(B) &= 2\int_0^{\frac{1}{k_3}} z^2 f(z)dz, & I'_{2n+1}(B') &= -2\int_0^{\frac{1}{k_3}} z^2 f(z)dz,\\
I'_{2n+1}(C) &= 2\int_0^{\frac{1}{k_2}} z^2 f(z)dz, & I'_{2n+1}(C') &= -2\int_0^{\frac{1}{k_2}} z^2 f(z)dz,\\
I'_{2n+1}(D) &= 2\int_0^{\frac{1}{k_1}} z^2 f(z)dz, & I'_{2n+1}(D') &= -2\int_0^{\frac{1}{k_1}} z^2 f(z)dz,
\end{aligned}\right\} \tag{6}$$

$z^2 f(z)$ returning to O with a negative sign.

$$I'_{2n}(A) = I'_{2n}(B) = I_{2n}(C) = I'_{2n}(D) = 0,$$

$$I'_{2n}(A') = I'_{2n}(B') = I'_{2n}(C') = I'_{2n}(D') = 0, \tag{7}$$

$z^2 f(z)$ returning to O with a positive sign.

Also, if z moves α times round a closed curve $OP_1\ P_2\ P_3\ P_4\ O$ as in fig. 2, surrounding both A and A',

$$I'_{\alpha}(A) + I'_{\alpha}(A') = 4\,\alpha \int_0^1 z^2 f(z)\,dz. \tag{8}$$

The most general route of integration from O to a point P, representing the variable $z = x + iy$, is easily seen to consist of a number of circuits round the eight points of ramification, and then of the rectilinear route from O to P. Let us first consider the effect of the points A and A' on the $\int_0^z f(z)\,dz$. We may suppose z to describe α times, as in fig. 2, a curve surrounding both A and A', and then to describe β times a curve surrounding either A or A', and finally the rectilinear route OP: in the first case we shall have

$$\int_0^z f(z)\,dz = \Big\{ I_{\alpha}(A) + I_{\alpha}(A') \Big\} + I_{\beta}(A) \pm \int_0^z [f(z)]\,dz$$

$$= 4\,\alpha \int_0^1 f(z)\,dz + I_{\beta}(A) \pm \int_0^z [f(z)]\,dz;$$

and in the second,

$$\int_0^z f(z)\,dz = 4\,\alpha \int_0^1 f(z)\,dz + I_{\beta}(A') \pm \int_0^z [f(z)]\,dz.$$

We see then, referring to (2) and (3), that in both cases the sign of $f(z)$ in the linear integral is positive if β is an even integer, and negative if β is an odd integer. The investigation of the general case is in every respect similar, and a little consideration leads us to the *general value* of the integral $\int_0^z f(z)\,dz$.

$$\int_0^z f(z)dz = a\,I(A) + b\,I(B) + c\,I(C) + d\,I(D) + (-1)^{a+b+c+d}\int[f(z)]\,dz, \quad (9)$$

and by parity of reasoning the *general value* of the integral $\int_0^z z^2 f(z)dz$ is

$$\int_0^z z^2 f(z)dz = a\,I'(A) + b\,I'(B) + c\,I'(C) + d\,I'(D) + (-1)^{a+b+c+d}\int_0^z [z^2 f(z)]\,dz, \quad (10)$$

a, b, c, and d being positive or negative integers.

Since $$U \equiv u\,(1-u)(1-k_1^2u)(1-k_2^2u)(1-k_3^2u),$$

it follows that for all values of u,

increasing from $\left\{\begin{array}{lll} -\infty & \text{to} & 0, \\ 1 & \text{to} & \dfrac{1}{k_3^2}, \\ \dfrac{1}{k_2^2} & \text{to} & \dfrac{1}{k_1^2}, \end{array}\right\}$ U is negative;

while for values of u,

increasing from $\left\{\begin{array}{lll} 0 & \text{to} & 1, \\ \dfrac{1}{k_3^2} & \text{to} & \dfrac{1}{k_2^2}, \\ \dfrac{1}{k_1^2} & \text{to} & \infty, \end{array}\right\}$ U is positive,

it being remembered that $k_3 > k_2 > k_1$.

Let us denote by $I\begin{pmatrix} u_1 \\ u_2 \end{pmatrix}$ the definite integral $\int_{u_2}^{u_1} \frac{du}{\sqrt{U}}$, the upper letter in the expression $I\begin{pmatrix} u_1 \\ u_2 \end{pmatrix}$ corresponding to the superior limit of the definite integral, and the lower to the inferior limit; and let, moreover, the definite integral

$$\int_{u_2}^{u_1} \frac{u\,du}{\sqrt{U}} \quad \text{be denoted by} \quad I'\begin{pmatrix} u_1 \\ u_2 \end{pmatrix}:$$

the six expressions

$$I\begin{pmatrix}0\\-\infty\end{pmatrix},\quad I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix},\quad I\begin{pmatrix}\frac{1}{k_1^2}\\\frac{1}{k_2^2}\end{pmatrix},\qquad I'\begin{pmatrix}0\\-\infty\end{pmatrix},\quad I'\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix},\quad I'\begin{pmatrix}\frac{1}{k_1^2}\\\frac{1}{k_2^2}\end{pmatrix},$$

are then imaginary, while the remaining six,

$$I\begin{pmatrix}1\\0\end{pmatrix},\quad I\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix},\quad I\begin{pmatrix}\infty\\\frac{1}{k_1^2}\end{pmatrix},\qquad I'\begin{pmatrix}1\\0\end{pmatrix},\quad I'\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix},\quad I'\begin{pmatrix}\infty\\\frac{1}{k_1^2}\end{pmatrix},$$

are real and positive. Moreover, Jacobi has shown that the above expressions are connected by the following relations :—

$$\left.\begin{aligned}
&I\begin{pmatrix}0\\-\infty\end{pmatrix}-I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix}+I\begin{pmatrix}\frac{1}{k_1^2}\\\frac{1}{k_2^2}\end{pmatrix}=0,\\
&I'\begin{pmatrix}0\\-\infty\end{pmatrix}-I'\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix}+I'\begin{pmatrix}\frac{1}{k_1^2}\\\frac{1}{k_2^2}\end{pmatrix}=0,\\
&I\begin{pmatrix}1\\0\end{pmatrix}-I\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix}+I\begin{pmatrix}\infty\\\frac{1}{k_1^2}\end{pmatrix}=0,\\
&I'\begin{pmatrix}1\\0\end{pmatrix}-I'\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix}+I'\begin{pmatrix}\infty\\\frac{1}{k_1^2}\end{pmatrix}=0.
\end{aligned}\right\}\qquad(11)$$

A reduction of the above expressions to the normal form of hyper-elliptic integrals; namely,

$$\int_0^{\frac{\pi}{2}}\frac{l+m\sin^2\phi}{\sqrt{(1-p^2\sin^2\phi)(1-q^2\sin^2\phi)(1-r^2\sin^2\phi)}},$$

will be found in Mr. M. Roberts' Tract "On the Additions of Elliptic and Hyper-Elliptic Integrals."

It is now easy to express $I(A)$, $I(B)$, &c., in terms of these integrals as follows:—

$$\left.\begin{aligned} I(A) &= I\begin{pmatrix}1\\0\end{pmatrix},\\ I(B) &= I\begin{pmatrix}1\\0\end{pmatrix} + I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix},\\ I(C) &= I\begin{pmatrix}1\\0\end{pmatrix} + I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix} + I\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix},\\ I(D) &= I\begin{pmatrix}1\\0\end{pmatrix} + I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix} + I\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix} + I\begin{pmatrix}\frac{1}{k_1^2}\\\frac{1}{k_2^2}\end{pmatrix}; \end{aligned}\right\} \qquad (12)$$

and a similar set of equations for $I'(A)$, $I'(B)$, &c.

The general values of the integrals $\int_0^z f(z)\,dz$ and $\int_0^z z^2 f(z)\,dz$, are, consequently—

$$\left.\begin{aligned} \int_0^z f(z)\,dz &= l\,I\begin{pmatrix}1\\0\end{pmatrix} + m\,I\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix} + \lambda\,I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix} + \mu\,I\begin{pmatrix}\frac{1}{k_1^2}\\\frac{1}{k_2^2}\end{pmatrix}\\ &\qquad + (-1)^l \int_0^z [f(z)]\,dz,\\ \int_0^z z^2 f(z)\,dz &= l\,I'\begin{pmatrix}1\\0\end{pmatrix} + m\,I'\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix} + \lambda\,I'\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix} + \mu\,I'\begin{pmatrix}\frac{1}{k_1^2}\\\frac{1}{k_2^2}\end{pmatrix}\\ &\qquad + (-1)^l \int [z^2 f(z)]\,dz. \end{aligned}\right\} \qquad (13)$$

Let us now put, for the sake of brevity,

$$l\,I\begin{pmatrix}1\\0\end{pmatrix}+m\,I\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix}+\lambda\,I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix}+\mu\,I\begin{pmatrix}\frac{1}{k_1^2}\\\frac{1}{k_2^2}\end{pmatrix}\equiv I,$$

$$l\,I'\begin{pmatrix}1\\0\end{pmatrix}+m\,I'\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix}+\lambda\,I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix}+\mu\,I\begin{pmatrix}\frac{1}{k_1^2}\\\frac{1}{k_2^2}\end{pmatrix}\equiv I',$$

$$\int_0^z f(z)\,dz\equiv L(z)\quad\int_0^z z^2 f(z)\,dz\equiv M(z),$$

so that 13 becomes

$$\begin{aligned}\int_0^z f(z)\,dz &= I+(-1)^l\int_0^z[f(z)]\,dz,\\ \int_0^z z^2 f(z)\,dz &= I'+(-1)^l\int_0^z[z^2 f(z)]\,dz.\end{aligned}\tag{14}$$

We see therefore that $z=(-1)^l z'$ satisfies *both* the transcendental equations

$$\begin{aligned}L(z)&=I+L(z')\\ M(z)&=I'+M(z').\end{aligned}\tag{15}$$

If we now assume $z^2+\zeta^2=1$, and put

$$f_1(\zeta)=\frac{1}{\sqrt{(1-\zeta^2)(h_1^2+k_1^2\zeta^2)(h_2^2+k_2^2\zeta^2)(h_3^2+k_3^2\zeta^2)}}$$

where

$$k_1^2 + h_1^2 = 1, \qquad k_2^2 + h_2^2 = 1, \qquad k_3^2 + h_3^2 = 1,$$

we find

$$\int_0^z f(z)\,dz = \int_\zeta^1 f_1(\zeta)\,d\zeta.$$

Now the function $f_1(\zeta)$ has eight points of ramification—

$$\zeta = \pm 1, \qquad \zeta = \pm i\frac{h_3}{k_3}, \qquad \zeta = \pm i\frac{h_2}{k_2}, \qquad \zeta = \pm i\frac{h_1}{k_1},$$

which we shall call A_1, A_1'; B_1, B_1'; C_1, C_1'; D_1, D_1'.

We shall then have

$$\left.\begin{aligned}
I(A_1) &= 2\int_0^1 f_1(\zeta)\,dz = 2\int_0^1 f(z)\,dz = I\begin{pmatrix}1\\0\end{pmatrix},\\
I(B_1) &= 2\int_0^{i\frac{h_3}{k_3}} f_1(\zeta)\,dz = 2\int_{\frac{1}{k_3}}^1 f(z)\,dz = -I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix},\\
I(C_1) &= 2\int_0^{i\frac{h_2}{k_2}} f_1(\zeta)\,d\zeta = 2\int_{\frac{1}{k_2}}^1 f(z)\,dz = -I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix} - I\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix},\\
I(D_1) &= 2\int_0^{i\frac{h_1}{k_1}} f_1(\zeta)\,d\zeta = 2\int_{\frac{1}{k_1}}^1 f(z)\,dz = -I\begin{pmatrix}\frac{1}{k_3^2}\\1\end{pmatrix} - I\begin{pmatrix}\frac{1}{k_2^2}\\\frac{1}{k_3^2}\end{pmatrix}\\
&\qquad - I\begin{pmatrix}\frac{1}{k_1^2}\\\frac{1}{k_2^2}\end{pmatrix}.
\end{aligned}\right\} \qquad (16)$$

The general values of the integrals $\int_0^\zeta f_1(\zeta)\,d\zeta$ and $\int_0^\zeta (1-\zeta^2)f_1(\zeta)\,d\zeta$ are then :—

$$\left.\begin{aligned} \int_0^\zeta f_1(\zeta)\,d\zeta &= I + (-1)^{l+\lambda}\int_0^\zeta [f_1(\zeta)]\,d\zeta, \\ \int_0^\zeta (1-\zeta^2)f_1(\zeta)\,d\zeta &= I' + (-1)^{l+\lambda}\int_0^\zeta [(1-\zeta^2)f_1(\zeta)]\,d\zeta. \end{aligned}\right\} \quad (17)$$

We see, then, that $\zeta = (-1)^{l+\lambda}\zeta'$ satisfies both the transcendental equations

$$\left.\begin{aligned} \int_0^{\zeta'} f_1(\zeta)\,d\zeta &= I + \int_0^{\zeta'} f_1(\zeta)\,d\zeta, \\ \int_0^{\zeta'} (1-\zeta^2)f_1(\zeta)\,d\zeta &= I' + \int_0^{\zeta'} (1-\zeta^2)f_1(\zeta)\,d\zeta\,; \end{aligned}\right\}$$

or, restoring to ζ its value in terms of z, and calling $\sqrt{1-z^2}\,D(z)$, we see that $D(z) = (-1)^{l+m}D(z')$ satisfies both the transcendental equations (15).

Let $D(k_1z) = \sqrt{1-k_1^2z^2}$, $D(k_2z) = \sqrt{1-k_2^2z^2}$, $D(k_3z) = \sqrt{1-k_3^2z^2}$. By a similar treatment of the functions $D(k_1z)$, $D(k_2z)$, $D(k_3z)$ I arrive at a number of like conclusions, which are found in the following scheme, each equation of which is agreeable to both the equations (15) :—

$$\left.\begin{aligned} 1^\circ.\quad z &= (-1)^l z'\,; \\ 2^\circ.\quad D(z) &= (-1)^{l+\lambda}D(z')\,; \\ 3^\circ.\quad D(k_3z) &= (-1)^{\lambda+m}D(k_3z')\,; \\ 4^\circ.\quad D(k_2z) &= (-1)^{m+\mu}D(k_2z')\,; \\ 5^\circ.\quad D(k_1z) &= (-1)^{\mu}D(k_1z'). \end{aligned}\right\} \quad (18)$$

I now consider the transcendental system:—

$$\left.\begin{aligned} L(z_1) + L(z_2) + I &= L(z_1') + L(z_2'), \\ M(z_1) + M(z_2) + I' &= M(z_1') + M(z_2'); \end{aligned}\right\} \quad (19)$$

which results from putting $L(z_3) = I$, $M(z_3) = I'$ in the system—

$$\left.\begin{aligned} L(z_1) + L(z_2) + L(z_3) &= L(z_1') + L(z_2'), \\ M(z_1) + M(z_2) + M(z_3) &= M(z_1') + M(z_2'). \end{aligned}\right\} \quad (20)$$

If in the latter system we consider z_3 as constant, there are four values of z_1^2 and z_2^2 which satisfy its algebraic integrals; for, since there is an ambiguity in the sign affecting the radical in $L(z)$ and $M(z)$, if we suppose one and the same radical always affected with the same sign, then there are as many algebraic solutions as there are modes of interpreting the equations:—

$$+\int_0^{z_1} \frac{dz}{\sqrt{Z}} \pm \int_0^{z_2} \frac{dz}{\sqrt{Z}} \pm \int_0^{z_3} \frac{dz}{\sqrt{Z}} = \text{constant},$$

$$+\int_0^{z_1} \frac{z^2 dz}{\sqrt{Z}} \pm \int_0^{z_2} \frac{z^2 dz}{\sqrt{Z}} \pm \int_0^{z_3} \frac{z^2 dz}{\sqrt{Z}} = \text{constant};$$

and these are readily seen to be four.

The particular case under consideration corresponds to that in which z_3 is zero, and there are then but two values of z_1^2 and z_2^2.

The following system of equations is now easily seen to be the algebraic equivalent of the transcendental system (19):—

$$\left.\begin{aligned}
&1°. && z_1 z_2 &&= (-1)^{l} z_1' z_2', \\
&2°. && D(z_1)\,D(z_2) &&= (-1)^{l+\lambda} D(z_1')\,D(z_2'), \\
&3°. && D(k_3 z_1)\,D(k_3 z_2) &&= (-1)^{\lambda+m} D(k_3 z_1')\,D(k_3 z_2'), \\
&4°. && D(k_2 z_1)\,D(k_2 z_2) &&= (-1)^{m+\mu} D(k_2 z_1')\,D(k_3 z_3'), \\
&5°. && D(k_1 z_1)\,D(k_1 z_2) &&= (-1)^{\mu} D(k_1 z_1')\,D(k_1 z_2');
\end{aligned}\right\} \quad (21)$$

and, since this system gives two values for z_1^2 and z_2^2, there is no other algebraic solution. For, let $l_1 = l_1 + l_2$, $m = m_1 + m_2$, $\lambda = \lambda_1 + \lambda_2$, $\mu = \mu_1 + \mu_2$, and I and I' become $I_1 + I_2$ and $I_1' + I_2'$, respectively.

Now, (21) gives the system:—

$$\left.\begin{aligned}
&1°. && z_1 = (-1)^{l_1} z_1' && z_2 = (-1)^{l_2} z_2', \\
&2°. && D(z_1) = (-1)^{l_1+\lambda_1} D(z_1'), && D(z_2) = (-1)^{l_2+\lambda_2} D(z_2'), \\
&3°. && D(k_3 z_1) = (-1)^{\lambda_1+m_1} D(k_3 z_1'), && \&c., \\
&4°. && D(k_2 z_1) = (-1)^{m_1+\mu_1} D(k_2 z_1'), && \&c., \\
&5°. && D(k_1 z_1) = (-1)^{\mu_1} D(k_1 z_1'). && \&c.;
\end{aligned}\right\} \quad (22)$$

or,

$$\left.\begin{aligned}
&1°. && z_1 = (-1)^{l_1} z_2', && z_2 = (-1)^{l_2} z_1', \\
&2°. && D(z_1) = (-1)^{l_1+\lambda_1} D(z_2'), && \&c., \\
&3°. && D(k_3 z_1) = (-1)^{\lambda_1+m_1} D(k_3 z_2'), && \&c., \\
&4°. && D(k_2 z_1) = (-1)^{m_1+\mu_1} D(k_2 z_2'), && \&c., \\
&5°. && D(k_1 z_1) = (-1)^{\mu_1} D(k_1 z_2'). && \&c.
\end{aligned}\right\} \quad (23)$$

But the system (22) gives

$$\left.\begin{aligned} L(z_1) &= I_1 + L(z_1'), \qquad L(z_2) = I_2 + L(z_2'), \\ M(z_1) &= I_1' + M(z_1'), \qquad M(z_2) = I_2' + M(z_2'); \end{aligned}\right\}$$

and therefore the system (19) is satisfied; and in the very same way the system (23) is shown to satisfy (19).

If now in (19) we put $z_1 = \sin\phi_1$, $z_2 = \sin\phi_2$, and put

$$\int_0^{\phi_1} \frac{d\phi}{\Delta(\phi)} + \int_0^{\phi_2} \frac{d\phi}{\Delta(\phi)} = \Phi,$$

$$\int_0^{\phi_1} \frac{\sin^2\phi\, d\phi}{\Delta(\phi)} + \int_0^{\phi_2} \frac{\sin^2\phi\, d\phi}{\Delta(\phi)} = \Phi',$$

we may consider the several products

$$\sin\phi_1 \sin\phi_2, \quad \cos\phi_1 \cos\phi_2, \quad \sqrt{1-k_3^2\sin^2\phi_1}\cdot\sqrt{1-k_3^2\sin^2\phi_2}, \quad \&c., \&c.,$$

as functions of the quantities Φ and Φ', which we shall express by the following notation :—

$$\sin\phi_1 \sin\phi_2 \begin{bmatrix} \Phi \\ \Phi' \end{bmatrix}; \qquad \cos\phi_1 \cos\phi_2 \begin{bmatrix} \Phi \\ \Phi' \end{bmatrix}, \qquad \&c.$$

Our final results, which readily flow from (11) and (21), are as follows :—

$$\sin\phi_1 \sin\phi_2 \begin{bmatrix} \Phi + \bar{I} \\ \Phi' + \bar{I}' \end{bmatrix} = (-1)^{l+n} \sin\phi_1 \sin\phi_2 \begin{bmatrix} \Phi \\ \Phi' \end{bmatrix}; \qquad (24)$$

$$\cos\phi_1 \cos\phi_2 \begin{bmatrix} \Phi + \bar{I} \\ \Phi' + \bar{I}' \end{bmatrix} = (-1)^{l+\lambda+n+\nu} \cos\phi_1 \cos\phi_2 \begin{bmatrix} \Phi \\ \Phi' \end{bmatrix};$$

$$\sqrt{1-k_3^2\sin^2\phi_1}\,\sqrt{1-k_3^2\sin^2\phi_2} \begin{bmatrix} \Phi + \bar{I} \\ \Phi' + \bar{I}' \end{bmatrix}$$

$$= (-1)^{\lambda+m+n+\nu} \sqrt{1-k_3^2\sin^2\phi_1}\,\sqrt{1-k_3^2\sin^2\phi_2} \begin{bmatrix} \Phi \\ \Phi' \end{bmatrix};$$

$$\sqrt{1-k_2^2\sin^2\phi_1}\,\sqrt{1-k_2^2\sin^2\phi_2} \begin{bmatrix} \Phi + \bar{I} \\ \Phi' + \bar{I}' \end{bmatrix}$$

$$= (-1)^{m+\mu+n+\nu} \sqrt{1-k_2^2\sin^2\phi_1}\,\sqrt{1-k_2^2\sin^2\phi_2} \begin{bmatrix} \Phi \\ \Phi' \end{bmatrix};$$

$$\sqrt{1-k_1^2\sin^2\phi_1}\,\sqrt{1-k_1^2\sin^2\phi_2} \begin{bmatrix} \Phi + \bar{I} \\ \Phi' + \bar{I}' \end{bmatrix}$$

$$= (-1)^{\mu+\nu} \sqrt{1-k_1^2\sin^2\phi_1}\,\sqrt{1-k_1^2\sin^2\phi_2} \begin{bmatrix} \Phi \\ \Phi' \end{bmatrix},$$

where

$$\bar{I} = l\,I\begin{pmatrix} 1 \\ 0 \end{pmatrix} + m\,I\begin{pmatrix} \frac{1}{k_2^2} \\ \frac{1}{k_1^2} \end{pmatrix} + n\,I\begin{pmatrix} \infty \\ \frac{1}{k_1^2} \end{pmatrix} + \lambda\,I\begin{pmatrix} \frac{1}{k_3^2} \\ 1 \end{pmatrix} + \mu\,I\begin{pmatrix} \frac{1}{k_1^2} \\ \frac{1}{k_2^2} \end{pmatrix} + \nu\,I\begin{pmatrix} 0 \\ -\infty \end{pmatrix};$$

$$\bar{I}' = l\,I'\begin{pmatrix} 1 \\ 0 \end{pmatrix} + m\,I'\begin{pmatrix} \frac{1}{k_2^2} \\ \frac{1}{k_1^2} \end{pmatrix} + n\,I'\begin{pmatrix} \infty \\ \frac{1}{k_1^2} \end{pmatrix} + \lambda\,I'\begin{pmatrix} \frac{1}{k_3^2} \\ 1 \end{pmatrix} + \mu\,I'\begin{pmatrix} \frac{1}{k_1^2} \\ \frac{1}{k_2^2} \end{pmatrix} + \nu\,I'\begin{pmatrix} 0 \\ -\infty \end{pmatrix};$$

I and I' being defined, as before, by the identical equations

$$I\begin{pmatrix} u_1 \\ u_2 \end{pmatrix} \equiv \int_{u_2}^{u_1} \frac{du}{\sqrt{u(1-u)(1-k_1^2u)(1-k_2^2u)(1-k_3^2u)}},$$

$$I'\begin{pmatrix} u_1 \\ u_2 \end{pmatrix} \equiv \int_{u_2}^{u_1} \frac{du}{\sqrt{u(1-u)(1-k_1^2u)(1-k_2^2u)(1-k_3^2u)}}.$$

We see, then, that $\sin\phi_1 \sin\phi_2$, $\cos\phi_1 \cos\phi_2$, &c., are periodic functions of two variables, Φ and Φ', each of which has four periods—two real and two imaginary—the nature of the periodicity being indicated by the equations (24).

VI.—*New Researches on Sun-heat and Terrestrial Radiation, and on Geological Climates. By the* Rev. Samuel Haughton, M.D. Dubl.; D.C.L. Oxon.; LL.D. Cantab.

[Read, January 10th, 1881.]

PART I.

SUN-HEAT RECEIVED, WITHOUT TAKING ACCOUNT OF THE ATMOSPHERE, AND SUN-HEAT LOST BY RADIATION, WITHOUT AN ATMOSPHERE AND WITH ONE.

The first study of this question was made by *Johann Heinrich Lambert*, in his book entitled *Pyrometrie oder vom maasse des Feuers und der Wärme*, Berlin (1779), *Achter Theil, von der Sonnenwärme*, p. 305.

Fourier, to whom the theory of heat owes more than to any other man, seems to have been not acquainted with, or to have ignored, the remarkable work done by Lambert, for he is nowhere mentioned in his *Theorie de la Chaleur*, Paris (1822).

Poisson, in his *Theorie mathematique de la Chaleur*, Paris (1835), does full justice to the great German mathematician and physicist, especially as to the matters in which Lambert had anticipated Fourier in the Mathematical Theory of Heat; but he adds nothing whatever to Lambert's Theory and Calculation of the Sun-heat delivered on the Earth at the several Latitudes.

Meech published his Treatise *On the relative Intensity of the Heat and Light*

of the Sun upon different Latitudes of the Earth in the Smithsonian Contributions to Knowledge, vol. ix.: Washington (1857).

This excellent Treatise confirms and expands all that Lambert had done in his *Pyrometrie*, but cannot be regarded as adding much to our knowledge of this interesting and important subject.

I shall now state, briefly, the chief results obtained by these writers and by myself, before proceeding to discuss the modifications of these results rendered necessary by taking into account the effects of the Earth's atmosphere.

Prop. 1.—*The quantity of Heat received by the Earth in any time is proportional to the Angle described in that time by the Earth's Radius Vector.**

According to the received laws of radiation of heat, the quantity of heat received by a given surface, perpendicular to the direction of the rays of radiating heat, is proportional to the inverse square of the distance of the heating body.

By Kepler's Law, the *radii vectores* of the planets describe equal areas in equal times; which Law is expressed, mathematically, by the equation

$$r^2 d\theta = h\,dt, \tag{1}$$

where

r = radius vector;

$d\theta$ = increment of the true anomaly;

h = constant;

dt = increment of the time.

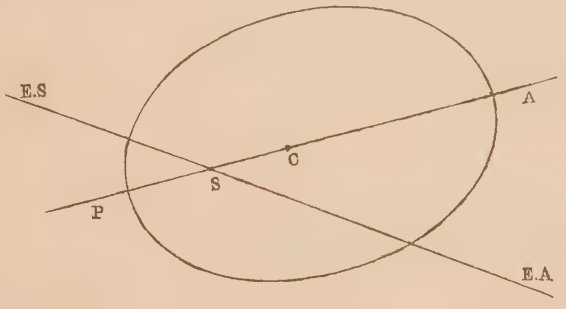
Therefore we have

$$\frac{dt}{r^2} = \frac{d\theta}{h} = \text{quantity of heat received in the time } (dt); \tag{2}$$

therefore, *in any time the quantity of heat received is proportional to the angle described by the radius vector in that time.* *Q. E. D.*

* This Law was first stated by Lambert.

Cor. 1.—It follows from this Law, that if *PSA* (fig. 1) denote the major axis of the Earth's orbit, *P* being the perihelion and *A* the aphelion; if *ES* and *EA* denote the spring and autumn equinox; that the total quantity of heat received by the Earth (including both northern and southern hemispheres) is the same in passing through *ES*, *A*, *EA*, and through *EA*, *P*, *ES*, no matter what may be the eccentricity of the Earth's orbit.



Cor. 2.—*Lambert* saw this consequence clearly, and adds:* Thus it may come to pass, in the case of Comets, that in traversing their 180° of longitude while near the Sun, they may receive as much Light and Heat in a few days or weeks as they shall in traversing the remaining part of their orbits during many centuries of years.

Of all the planets, he adds, Mercury has the greatest eccentricity; and this planet receives from the Sun, during the $32\frac{3}{4}$ days while he is nearest him, as much Light and Heat as he receives during the $53\frac{1}{5}$ days while he is farthest from him.

Prop. II.—*The total quantity of Heat received by the Earth in a Year is inversely proportional to the Minor Axis of the Earth's Orbit.*†

By Kepler's Law,

$$r^2 d\theta = h\,dt.$$

Now, $r^2 d\theta$ is twice the area described by the *radius vector* in the time (dt). Therefore, in describing the entire orbit

$$2\pi ab = hT,$$

where T = periodic time of Earth's revolution, and πab = area of ellipse,

* I translate freely from the German.

† This Law, I believe, was first stated by Sir John Herschel.

whose semiaxes are a and b. Therefore

$$h = \frac{2\pi ab}{T}; \tag{3}$$

therefore, by equation (2),

$$\text{Total heat received in one revolution} = \frac{2\pi}{h} = \frac{T}{ab}. \tag{4}$$

In this equation T and a are constant, by the laws of gravitation, and consequently the total heat received in one year varies inversely as b, the minor axis of the Earth's orbit. *Q.E.D.*

Cor.—By the geometry of the Ellipse

$$b = a\sqrt{1 - e^2}, \tag{5}$$

or

$$b = a\,(1 - \tfrac{1}{2}e^2),$$

neglecting smaller terms.

The eccentricity of the Earth's orbit, which is at present

$$e = 0{\cdot}0168,$$

may increase to a maximum of

$$e = 0{\cdot}07785.*$$

Hence, if H denote the general amount of Sun-heat received by the Earth, when her orbit is circular, the annual amount of Sun-heat received, when her orbit is most eccentric, will be

$$H(1 - 0{\cdot}00303):$$

that is to say, that the total variation of annual Sun-heat received by the

* The time when this *maximum possibile* takes place is unknown. The following estimates of the maximum have been made:—

Lagrange, ...	0·07641
Leverrier, ...	0·07775
Stockwell, ...	0·06939
Mean, . .	**0·07785**

Earth, due to variation of eccentricity of orbit, is only $\frac{1}{333}$rd part of the total heat received.

This variation of Sun-heat received is quite inadequate to affect geological climates sensibly.

Or, in other words, if the Sun at present, at the Equator, be sufficient in one year to melt 100 feet of ice, it would melt $3\frac{1}{2}$ inches less when the eccentricity of the Earth's orbit was at its maximum.

Prop. III.—*The difference between the quantities of Heat received in Summer and Winter, in the northern and southern Hemispheres, is always equal, and independent of the position of the line of Equinoxes.*

Let N_s, N_w, denote the quantities of heat received in the summer and winter halves of the year by the northern hemisphere; and let S_s, S_w denote the corresponding quantities of heat for the southern hemisphere; then, whatever be the position of the line of equinoxes (fig. 1), since the total heat received by the whole Earth is the same in traversing the paths *ES*, *A*, *EA*, and *EA*, *P*, *ES*, we have

$$N_s + S_w = N_w + S_s.$$

Hence we have

$$N_s - N_w = S_s - S_w. \qquad (6)$$

Q. E. D.

Prop. IV.—*It is required to find the Sun-heat on any Day at any Latitude between the Equator and the Polar Circles.*

The quantity of Sun-heat received by a given surface, anywhere, is

$$\frac{A}{r^2} \cdot \cos z \, dh; \qquad (7)$$

where

A = a solar constant;

r = distance of Earth from Sun;

z = zenith distance of Sun;

h = Sun's hour angle.

Integrating this, from sunrise to sunset, we have

$$\frac{2A}{r^2}\Big\{\sin\lambda\sin\delta\times H+\cos\lambda\cos\delta\sin H\Big\}, \tag{8}$$

where

λ = latitude of place;

δ = Sun's declination;

H = hour of sunset.

But, since

$$\cos H=-\tan\lambda\tan\delta,$$

equation (8) may be thus written: *Total Sun-heat received in one day*

$$=\frac{2A}{r^2}\sin\lambda\sin\delta\{H-\tan H\}. \tag{9}$$

Expanding (9) in terms of $\cos H$, we have, since

$$H=\frac{\pi}{2}-\Big\{\cos H+\frac{1}{2}\cdot\frac{\cos^3 H}{3}+\frac{1\cdot3}{2\cdot4}\cdot\frac{\cos^5 H}{5}+\frac{1\cdot3\cdot5}{2\cdot4\cdot6}\cdot\frac{\cos^7 H}{7}+\&c.;$$

and

$$\tan H=\frac{\sqrt{1-\cos^2 H}}{\cos H}$$

$$=\frac{1}{\cos H}\Big\{1-\frac{\cos^2 H}{2}-\frac{1}{1\cdot2}\cdot\frac{\cos^4 H}{2^2}-\frac{1\cdot3}{1\cdot2\cdot3}\cdot\frac{\cos^6 H}{2^3}-\&c.;$$

$$H-\tan H=\frac{\pi}{2}-\frac{1}{\cos H}-\frac{\cos H}{2}-\frac{\cos^3 H}{24}-\frac{\cos^5 H}{80}-\frac{5\cos^7 H}{896}-\&c.$$

But,

$$\cos H=-\tan\lambda\tan\delta=-\frac{\tan\lambda\sin\delta}{\sqrt{1-\sin^2\delta}}$$

$$=-\tan\lambda\sin\delta\Big\{1+\frac{\sin^2\delta}{2}+\frac{1\cdot3}{1\cdot2}\cdot\frac{\sin^4\delta}{2^2}+\frac{1\cdot3\cdot5}{1\cdot2\cdot3}\cdot\frac{\sin^6\delta}{2^3}+\&c.,$$

and

$$\frac{1}{\cos H}=-\frac{\cot\lambda}{\sin\delta}\Big(1-\frac{\sin^2\delta}{2}-\frac{1}{1\cdot2}\cdot\frac{\sin^4\delta}{2^2}-\frac{1\cdot3}{1\cdot2\cdot3}\cdot\frac{\sin^6\delta}{2^3}-\&c.$$

Hence, finally, *the Sun-heat received in one day, at any place and time, is*

$$\frac{2A}{r^2}\sin\lambda\sin\delta(H-\tan H) \tag{10}$$

$$= \frac{2A}{r^2}\left|\begin{array}{l} \frac{\pi}{2}\sin\lambda\sin\delta^* \\ +\cos\lambda\left(1-\frac{\sin^2\delta}{2}-\frac{1}{1.2}\cdot\frac{\sin^4\delta}{2^2}-\frac{1.3}{1.2.3}\cdot\frac{\sin^6\delta}{2^3}-\&c.\right. \\ +\frac{\tan\lambda\sin\lambda}{2}\left(\sin^2\delta+\frac{\sin^4\delta}{2}+\frac{1.3}{1.2}\cdot\frac{\sin^6\delta}{2^2}+\&c.\right. \\ +\frac{\tan^3\lambda\sin\lambda}{24}\left(\sin^4\delta+\frac{3}{2}\sin^6\delta+\&c.\right. \\ +\frac{\tan^5\lambda\sin\lambda}{80}\left(\sin^6\delta+\&c.\right. \\ +\&c. \end{array}\right.$$

Or, since

$$\sin\delta = \sin\Delta\sin l,$$

where

Δ = obliquity of Ecliptic,

l = Sun's longitude

$$= \frac{2A}{r^2}\left|\begin{array}{l} \frac{\pi}{2}\sin\lambda\sin\Delta\,.\,\sin l \\ +\cos\lambda\left|\begin{array}{l} 1-\frac{\sin^2\Delta}{4}(1-\cos 2l) \\ -\frac{\sin^4\Delta}{64}(3-4\cos 2l+\cos 4l) \\ -\frac{\sin^6\Delta}{512}(10-15\cos 2l+6\cos 4l-\cos 6l) \\ -\&c.,\ \&c. \end{array}\right. \end{array}\right.$$

* It will be noted that this term is the only one that changes sign when the sign of δ changes; *i.e.* in passing from summer to winter.

$$= \frac{2A}{r^2} \left| \begin{array}{l|l} + \tan\lambda \sin\lambda & \frac{\sin^2\Delta}{4}(1 - \cos 2l) \\ & \quad + \frac{\sin^4\Delta}{32}(3 - 4\cos 2l + \cos 4l) \\ & \quad + \frac{3\sin^6\Delta}{512}(10 - 4\cos 2l + 6\cos 4l - \cos 6l) \\ & \quad + \&c. \\ + \tan^3\lambda \sin\lambda & \frac{\sin^4\Delta}{192}(3 - 4\cos 2l + \cos 4l) \\ & \quad + \frac{\sin^6\Delta}{512}(10 - 4\cos 2l + \&c.) \\ & \quad + \&c. \\ + \tan^5\lambda \sin\lambda & \frac{\sin^6\Delta}{2560}(10 - 4\cos 2l + \&c.) \\ + \&c., \&c. & \quad + \&c. \end{array} \right. \qquad (11)$$

Prop. V.—*It is required to find the Sun-heat received in a Year at any Latitude between the Equator and the Polar Circles.*

In order to find the annual Sun-heat received at any latitude, it is necessary to sum the daily integrals (11) for the total number of days in the year. This gives us

$$\textit{Total annual Sun-heat} = \Sigma \frac{2A}{r^2} \left\{ a_0 \delta t + \begin{array}{l} a_1 \cos l\delta t + a_2 \cos 2l\delta t + \&c. \\ b_1 \sin l\delta t + b_2 \cos 2l\delta t + \&c. \end{array} \right.$$

where

$$\begin{aligned} a_0 &= \cos\lambda \left[1 - \frac{\sin^2\Delta}{4} - \frac{3\sin^4\Delta}{64} - \frac{10\sin^6\Delta}{512} - \&c. \right. \\ &+ \tan\lambda \sin\lambda \left[\frac{\sin^2\Delta}{4} + \frac{3\sin^4\Delta}{32} + \frac{30\sin^6\Delta}{512} + \&c. \right. \\ &+ \tan^3\lambda \sin\lambda \left[\frac{3\sin^4\Delta}{192} + \frac{10\sin^6\Delta}{512} + \&c. \right. \end{aligned} \qquad (12)$$

$$+ \tan^5\lambda \sin\lambda \left[\frac{10 \sin^6\Delta}{2560} + \&c.$$

$$+ \&c., \&c.;$$

or, substituting for Δ its value ($23° 28'$),

$$\begin{aligned} a_0 &= 0{\cdot}95910 \cos\lambda + 0{\cdot}04187 \tan\lambda \sin\lambda \\ &\quad + 0{\cdot}00047 \tan^3\lambda \sin\lambda \\ &\quad + 0{\cdot}000015 \tan^5\lambda \sin\lambda \\ &\quad + \&c. \end{aligned} \qquad (12\ bis)$$

$$a_1 = 0,$$

$$b_1 = \frac{\pi}{2} \sin\lambda \sin\Delta = 0{\cdot}62551 \sin\lambda, \qquad (13)$$

$$\begin{aligned} a_2 &= \cos\lambda \left[\frac{\sin^2\Delta}{4} + \frac{4 \sin^4\Delta}{64} + \frac{15 \sin^6\Delta}{512} + \&c.\right. \\ &\quad - \tan\lambda \sin\lambda \left[\frac{\sin^2\Delta}{4} + \frac{4 \sin^4\Delta}{32} + \frac{12 \sin^6\Delta}{512} + \&c.\right. \\ &\quad - \tan^3\lambda \sin\lambda \left[\frac{4 \sin^4\Delta}{192} + \frac{4 \sin^6\Delta}{512} + \&c.\right. \\ &\quad - \tan^5\lambda \sin\lambda \left[\frac{4 \sin^6\Delta}{2560} + \&c.\right. \\ &\quad - \&c., \&c. \end{aligned} \qquad (14)$$

$$b_2 = 0;$$

or, finally,

$$\begin{aligned} a_2 &= 0{\cdot}04133 \cos\lambda - 0{\cdot}04288 \tan\lambda \sin\lambda \\ &\quad - 0{\cdot}00330 \tan^3\lambda \sin\lambda; \\ b_2 &= 0 \qquad - \&c., \&c. \end{aligned} \qquad (14\ bis)$$

$$a_3 = 0, \qquad (15)$$

$$b_3 = 0;$$

$$a_4 = -\cos\lambda \left[+\frac{\sin^4\Delta}{64}+\frac{15\sin^6\Delta}{512}+\&c.\right.$$
$$+\tan\lambda\sin\lambda\left[\frac{\sin^4\Delta}{32}+\frac{18\sin^6\Delta}{512}+\&c.\right.$$
$$+\tan^3\lambda\sin\lambda\left[\frac{\sin^4\Delta}{192}+\frac{6\sin^6\Delta}{512}+\&c.\right.$$
$$+\tan^5\lambda\sin\lambda\left[\frac{6\sin^6\Delta}{2560}+\&c.\right.$$
$$+\&c.,\ \&c. \qquad (16)$$
$$b_4 = 0;$$

or, finally,

$$a_4 = -0{\cdot}00051\cos\lambda + 0{\cdot}00092\tan\lambda\sin\lambda + 0{\cdot}00018\tan^3\lambda\sin\lambda + \&c.$$
$$b_4 = 0. \qquad (16\,bis)$$

We therefore obtain, finally,

$$\textit{Total Annual Sun-heat} = 2A\left|\begin{array}{l} a_0\Sigma\left(\frac{\delta t}{r^2}\right)+b_1\Sigma\left(\frac{\sin l\delta t}{r^2}\right)+a_2\Sigma\left(\frac{\cos 2l\delta t}{r^2}\right) \\ \quad +a_4\Sigma\left(\frac{\cos 4l\delta t}{r^2}\right)+a_6\Sigma\left(\frac{\cos 6l\delta t}{r^2}\right) \\ \quad +\&c.\,; \end{array}\right. \qquad (17)$$

where $\delta t = 24$ hours—

a_0 is an ordinary quantity;
b_1 is a quantity of the order, $\sin\Delta$;
a_2 is a quantity of the order, $\sin^2\Delta$;
a_4 is a quantity of the order, $\sin^4\Delta$;
a_6 is a quantity of the order, $\sin^6\Delta$;
&c., &c.

Now, since

$$\begin{aligned} \Delta &= 23^\circ 28', \\ \sin\Delta &= 0{\cdot}3982, \\ \sin^2\Delta &= 0{\cdot}1586, \\ \sin^4\Delta &= 0{\cdot}0251, \quad e = 0{\cdot}0168, \\ \sin^6\Delta &= 0{\cdot}0040, \end{aligned}$$

we see that a_4 is a quantity of the same order as e, so that by our previous calculations, which include all terms up to $\sin^6\Delta$, our approximation is carried as far as the first power of the eccentricity of the Earth's orbit.

In equation (17) we have

$$\frac{\delta t}{r^2} = \frac{\delta\theta}{h} = \frac{\delta l}{h} = \frac{T\delta l}{2\pi ab}. \tag{18}$$

Introducing this value of $\frac{\delta t}{r^2}$, we find

$$\textit{Sun-heat received} = \frac{AT}{\pi ab}\Big| \; a_0\int\delta l + b_1\int \sin l\delta l + a_2\int\cos l\delta l + \&c.\,;$$

or, integrating,

$$\textit{Sun-heat received} = \frac{AT}{\pi ab}\Big| \; a_0 l - b_1\cos l + \frac{a_2}{2}\sin 2l + \frac{a_4}{4}\sin 4l + \&c. + const. \tag{19}$$

If this be taken for the whole year, all the periodic terms will disappear, and the result gives

$$\textit{Total Annual Sun-heat} = \frac{AT}{\pi ab}\times 2\pi a_0$$

$$= \frac{2A\times T}{ab}\Big| \; 0{\cdot}95910\cos\lambda + 0{\cdot}04187\tan\lambda\sin\lambda + 0{\cdot}00047\tan^3\lambda\sin\lambda + 0{\cdot}000015\tan^5\lambda\sin\lambda + \&c. \tag{20}$$

Cor. 1.—Since equation (20) is a function of $\cos\lambda$, $\tan\lambda\sin\lambda$, &c., $\tan^{2n-1}\lambda\sin\lambda$, it does not change sign in passing from the northern to the southern hemisphere, and therefore

$$N_s + N_w = S_s + S_w. \tag{22}$$

Combining this equation with Prop. III. (6),

$$N_s - N_w = S_s - S_w,$$

we obtain, finally,

$$N_s = S_s, \qquad N_w = S_w; \tag{23}$$

or, *the Northern and Southern Hemispheres receive equal quantities of Sun-heat in Summer, and equal (though different) quantities of Sun-heat in Winter, whatever may be the Eccentricity of the Earth's Orbit.*

Cor. 1.—The heat received in Summer by either hemisphere is found by taking (19) from $l = \pi$ to $l = 0$, which gives

$$N_s = S_s = \frac{AT}{\pi ab}\left(a_0\pi + 2b_1\right); \tag{24}$$

and the heat received in Winter by either hemisphere is found by taking (19) from $l = 2\pi$ to $l = \pi$, or

$$N_w = S_w = \frac{AT}{\pi ab}\left(a_0\pi - 2b_1\right). \tag{25}$$

Cor. 2.—Hence, the *proportion which the excess of heat in Summer or the defect of heat in Winter bears to the whole annual heat received* is

$$\frac{b_1}{\pi a_0}. \tag{26}$$

If we calculate the coefficients from equations (12), (13) for the latitude 60°, we find

$$a_0 = 0{\cdot}54467,$$
$$b_1 = 0{\cdot}54171;$$

from which we find, at 60° lat.,

$$\frac{\textit{Excess of Summer Heat}}{\textit{Total Annual Heat}} = \frac{1}{3{\cdot}157}. \tag{27}$$

Prop. VI.—*It is required to find the Sun-heat received in a Year at any Latitude inside the Polar Circles.*

At any place inside the Polar Circles the Sun-heat received, as long as the Sun rises and sets, will be expressed by the equation (19); so that, if l_0 be the Sun's longitude, corresponding to the Sun's declination, when it ceases to rise and set, we have, doubling the sum from $l=0$ to $l=l_0$,

Summer and Winter Sun-heat, while the Sun rises and sets,

$$= \frac{AT}{\pi ab} \left| \begin{array}{l} a_0 \times 2l_0 \pm 2b_1(1-\cos l_0) \\ \qquad + \frac{a_2}{1}\sin 2l_0 \\ \qquad\qquad + \frac{a_4}{2}\sin 4l_0 \\ \qquad\qquad\qquad + \&c., \end{array} \right. \tag{28}$$

the negative sign of b_1 corresponding to Winter.

To this must be added the Sun-heat received while the Sun remains always above the horizon, which is thus found. The Sun-heat received in one day is

$$\frac{A}{r^2}\int_0^{2\pi}\cos z\,dh = \frac{A}{r^2}\int_0^{2\pi}\sin\lambda\sin\delta\,dh + \frac{A}{r^2}\int_0^{2\pi}\cos\lambda\cos\delta\cos h\,dh$$

$$= \frac{2A\pi}{r^2}\sin\lambda\sin\delta = 2A\pi\sin\lambda\sin\Delta\times\frac{\sin l}{r^2};$$

and the sum of these terms must be taken for all the days in which the Sun does not rise or set. This sum is

$$2A\times\pi\sin\lambda\sin\Delta\times\Sigma\frac{\sin l\,\delta t}{r^2};$$

which becomes, by equations (1), (3), and (13),

$$\frac{AT}{\pi ab}\times 2b_1\times\Sigma\sin l\,\delta l = -\frac{AT}{\pi ab}\times 2b_1\times\cos l + \text{const.} \tag{29}$$

This result, taken from $l = l_0$ to $l = \pi - l_0$, gives

Summer and Winter Sun-heat, while the Sun does not rise or set,

$$= \pm \frac{AT}{\pi ab}\left(2b_1 \times 2 \cos l_0\right), \tag{30}$$

where the negative sign of b_1 corresponds to Winter. Adding together (28) and (30), we find

Total Summer and Winter Sun-heat for Latitudes inside the Polar Circles

$$= \frac{AT}{\pi ab}\left(a_0 \times 2l_0 \pm 2b_1 (1 + \cos l_0) + \frac{a_2}{1} \sin 2l_0 + \frac{a_4}{2} \sin 4l_0 + \&c.\right). \tag{31}$$

Hence, *the Total annual Sun-heat becomes*

$$\frac{AT}{\pi ab} \left| \begin{array}{l} \times a_0 \times 4l_0 \\ \qquad + a_2 \sin 2l_0 \\ \qquad\qquad + \frac{a_4}{2} \sin 4l_0 \\ \qquad\qquad\qquad + \&c. \end{array} \right. \tag{32}$$

Cor. 1.—At the Polar Circles $l_0 = \frac{\pi}{2}$; hence, equation (31) becomes

Total Summer and Winter Sun-heat at the Polar Circles,

$$= \frac{AT}{\pi ab}\left(\pi a_0 \pm 2b_1\right), \tag{33}$$

which coincides with equations (24) and (25).

Cor. 2.—At the Polar Circles, equation (32) becomes—

Total annual Sun-heat at the Polar Circles

$$= \frac{AT}{\pi ab} \times 2\pi a_0, \tag{34}$$

which coincides with equation (20). Hence we see that the formulae which express the Sun-heat from the Equator to the Polar Circles pass, without breach of continuity, into those which express the Sun-heat inside the Polar Circles.

Cor. 3.—At the Poles, where the Sun never rises or sets, equation (28)

disappears, because $l_0 = 0$, and the Sun-heat is expressed altogether by equation (30), which gives

Total Sun-heat in Summer and Winter at the Poles

$$= \pm \frac{AT}{\pi ab} \times 4b_1. \tag{35}$$

Cor. 4.—It appears from (20) and (35) that

$$\frac{\textit{Annual Sun-heat at Equator}}{\textit{Annual Sun-heat at Poles}} = \frac{\pi a_0}{4b_1}. \tag{36}$$

Substituting the proper values, I find this ratio to be 0·4152. Mr. Meech gives it as 0·4151.

Cor. 5.—Mr. Meech gives the third column of the following Table of Annual Sun-heats, which may be accepted as accurate:—

Annual Sun-heat.

Latitude.	Units of Ice melted.	Calc. Temp.	Actual Temp.
Degrees.	Feet.	Degrees, F.	Degrees, F.
0	100·0	81·50	80·1
5	99·7	81·22	—
10	98·6	80·38	81·0
15	96·9	78·97	—
20	94·5	77·03	77·6
25	91·5	74·57	—
30	87·9	71·63	67·6
35	83·7	68·21	—
40	79·0	64·39	56·5
45	73·9	60·20	—
50	68·4	55·73	43·4
55	62·7	51·06	—
60	56·9	46·36	29·3
65	51·4	41·92	—
70	47·4	38·61	14·4
75	44·7	36·42	—
80	42·9	34·95	4·5
85	41·9	34·10	—
90	41·5	33·83	—

It will be observed that the difference between the Sun-heat temperature and the actual temperature increases rapidly with the latitude, partly in consequence of the omission of the effects of radiation of heat into space, and partly in consequence of the omission of the effects of the Earth's atmosphere.

Prop. VII.—*It is required to calculate the Effects of Radiation into Space upon the Temperature of any place on the Surface of the Earth.*

The rate of increase of temperature, by reason of Sun-heat, at any place is (7)—

$$\frac{d\theta}{dh} = \frac{A \cos z}{r^2}, \tag{37}$$

where θ is the temperature of the place.

Neglecting the atmosphere, the rate of decrease of temperature, by reason of radiation, according to Rossetti's Law of Cooling,* at any place, is

$$\frac{d\theta}{dh} = -B(\theta + 460)^3; \tag{38}$$

hence, the rate of change of temperature at any place is

$$\frac{d\theta}{dh} = \frac{A \cos z}{r^2} - B(\theta + 460)^3. \tag{39}$$

The integral of this, for one day, is

$$\theta = \frac{A}{r^2}\int_{-H}^{+H} \cos z\, dh - B\int_0^{2\pi} (\theta + 460)^3\, dh. \tag{40}$$

The first term of this integral, depending upon Sun-heat, has been already discussed, and summed, for all latitudes for the entire year; the sum being a function of the latitude only, and the same for the Northern and Southern Hemispheres.

It is well known that the maximum and minimum diurnal temperatures do not occur at noon and midnight, but some hours afterwards; and that the maximum and minimum annual temperatures do not occur at Mid-summer and Midwinter, but some days afterwards. This Law of Diurnal

* Haughton, *Six Lectures on Physical Geography*, p. 347, *et seq.*

and Annual Temperature presents so close an analogy to the Law of the Diurnal and Annual Tides, that we are justified in assuming for its mathematical expression formulae based upon the well-known expressions for those Tides.

I therefore assume, for the diurnal temperature, the following law:—

$$\theta = \theta_0 + \begin{matrix} \pm a_1 \cos h^* \\ \pm b_1 \sin h \end{matrix}, \qquad (41)$$

where θ_0 expresses the mean diurnal temperature.

Substituting the foregoing value of θ, it is easy to see that the

Diurnal Radiation

$$= -B\int_0^{2\pi}(\theta + 460)^3 dh = -B\int_0^{2\pi}\left(\theta_0 + 460 + \begin{matrix} a_1 \cos h \\ b_1 \sin h \end{matrix}\right)^3 dh$$

$$= -2\pi B(\theta_0 + 460)^3 \left\{1 + \frac{3}{2}\frac{(a_1^2 + b_1^2)}{(\theta_0 + 460)^2}\right\}; \qquad (42)$$

where

$2\sqrt{a_1^2 + b_2}$ = diurnal range of temperature;

$\tan^{-1}\left(\frac{b_1}{a_1}\right) = \left\{\begin{matrix} \text{retardation or acceleration of maximum or minimum} \\ \text{diurnal temperature, referred to noon or midnight.} \end{matrix}\right.$

As the fraction $\frac{3}{2}\frac{a_1^2 + b_1^2}{(\theta_0 + 460)^2}$ may be written $\frac{3}{8} \times \left(\frac{\text{Diurnal range}}{\theta_0 + 460}\right)^2$, it is evidently a small fraction, and may be neglected on a first approximation.

Hence we have

$$\textit{Diurnal Radiation} = -2\pi B(\theta_0 + 460)^3. \qquad (43)$$

* The ± signs here used depend upon the hemisphere. If h be the hour angle at any place in the Northern Hemisphere, $h + 180$ will be the corresponding hour angle at its antipode in the Southern Hemisphere; midway corresponding to midnight, and so on. But

$$\cos(h + 180) = -\cos h,$$
$$\sin(h + 180) = -\sin h.$$

In like manner we may assume for the annual radiation of Heat—

$$\theta_0 = \Theta_0 \begin{matrix} \pm \alpha_1 \cos l \\ \pm \beta_1 \sin l \end{matrix}, \quad (44)$$

where Θ_0 is the mean annual temperature and l is the Sun's longitude, and where

$2\sqrt{\alpha_1^2 + \beta_1^2}$ = annual range of temperature;

$\tan^{-1}\left(\frac{\beta_1}{\alpha_1}\right)$ = { retardation or acceleration of annual maximum or minimum of temperature, referred to Midsummer or Midwinter.

This gives us, as before,

$$\textit{Annual Radiation} = -2\pi B \{(\theta_0 + 460)^3 \delta t$$

$$= -2\pi B \left\{ \left((\Theta_0 + 460) \begin{matrix} \pm \alpha_1 \cos l \\ \pm \beta_1 \sin l \end{matrix} \right)^3 \delta t \right\}$$

taken for the whole year.

Now we have, by the theory of planetary motion—

$$\delta t = \frac{T(1-e^2)^{\frac{3}{2}}}{2\pi} \times \frac{\delta\theta}{(1+e\cos\theta)^2}, \quad (45)$$

and

$$l = \theta + \varpi,$$

where

θ = true anomaly measured from perihelion;

ϖ = longitude of perihelion.

* The ± signs here indicate the hemisphere considered, for the reason given in the note to equation (41). For if l be the Sun's longitude in the Northern Hemisphere at Midsummer, it is then Midwinter in the Southern Hemisphere; and we must write $l + 180$ to obtain the Southern Hemisphere Midsummer.

Hence,

$$\textit{Annual Radiation} = -BT(1-e^2)^{\frac{3}{2}}\Sigma_0^{2\pi}\left((\Theta_0+460+\begin{matrix}\alpha_1\cos(\theta+\varpi)\\ \beta_1\sin(\theta+\varpi)\end{matrix}\right)^3\times\frac{\delta\theta}{(1+e\cos\theta)^2}. \quad (46)$$

The quantity under the sign of summation is—

$$\left\{(\Theta_0+460)^3 + 3(\Theta_0+460)^2\left\{\begin{matrix}(\alpha_1\cos\varpi+\beta_1\sin\varpi)\cos\theta\\ -(\alpha_1\sin\varpi-\beta_1\cos\varpi)\sin\theta\end{matrix}\right\} + 3(\Theta_0+460)\left\{\begin{matrix}(\alpha_1\cos\varpi+\beta_1\sin\varpi)\cos\theta\\ -(\alpha_1\sin\varpi-\beta_1\cos\varpi)\sin\theta.\end{matrix}\right\}^2 + \left\{\begin{matrix}(\alpha_1\cos\varpi+\beta_1\sin\varpi)\cos\theta\\ -(\alpha_1\sin\varpi-\beta_1\cos\varpi)\sin\theta\end{matrix}\right\}^3\right\}$$
$$\times\{1-2e\cos\theta+3e^2\cos^2\theta-\&c.\}\delta\theta.$$

In the summation for the entire year, the periodic terms depending on θ (the true anomaly) will disappear, and the final result will take the form—

$$\textit{Annual Radiation} = -2\pi BT(1-e^2)^{\frac{3}{2}} \times\left\{\begin{matrix}(\Theta_0+460)^3\left(1+\frac{3e^2}{2}\right)+(\Theta_0+460)\times\frac{3(\alpha_1^2+\beta_1^2)}{2}\\ \pm(\Theta_0+460)^2\times 3e(\alpha_1\cos\varpi+\beta_1\sin\varpi).\end{matrix}\right\} \quad (47)$$

This expression for annual radiation has the form

$$A_0\begin{matrix}\pm A_1\cos\varpi\\ \pm B_1\sin\varpi\end{matrix}\ ^*, \quad (48)$$

and therefore denotes a secular variation depending on the motion of the perihelion referred to the line of Equinoxes.

* The ± signs have the same meaning as in equations (41) and (44).

We have, therefore,

$$A_0 = (\Theta_0 + 460)^3 \left\{1 + \frac{3e^2}{2} + \frac{3(\alpha_1^2 + \beta_1^2)}{2(\Theta_0 + 460)^2}\right\},$$

$$A_1 = \pm (\Theta_0 + 460)^2 \times 3e\alpha_1, \qquad (49)$$

$$B_1 = \pm (\Theta_0 + 460)^2 \times 3e\beta_1;$$

and

$$2\sqrt{A_1^2 + B_1^2} = \text{secular range of Heat-variation;}$$

$$\tan^{-1}\left(\frac{B_1}{A_1}\right) = \begin{cases}\text{angle between the line of maximum and} \\ \text{minimum Heat and line of Apsides.}\end{cases}$$

As before, the expression

$$\frac{3(\alpha_1^2 + \beta_1^2)}{2(\Theta_0 + 460)^2}$$

will be very small; and therefore we may write down, neglecting terms of the second order—

Annual Radiation

$$= -2\pi BT(\Theta_0 + 460)^3 \left(1 \pm \frac{3e\alpha_1}{\Theta_0 + 460}\cos\varpi \pm \frac{3e\beta_1}{\Theta_0 + 460}\sin\varpi\right).* \qquad (50)$$

* Dr. Ball informs me that the longitude of the Earth's perihelion, on the 1st January, 1881, was 100° 53′ 14″·2. Consequently, the longitude of the Sun's perigee on that day was

$$\varpi = 280° 15' 14''{\cdot}2.$$

This gives us

$$\sin\varpi = -0{\cdot}9820,$$

$$\cos\varpi = +0{\cdot}1888.$$

Hence, the *plus* sign in equation (50) belongs to the Northern Hemisphere, which is now obtaining the advantage of the *nearly minimum* radiation; and the *minus* sign belongs to the Southern Hemisphere, which is now suffering the disadvantage of the *nearly maximum* radiation.

The heat received from the Sun in one year is, (20), neglecting terms depending on e^2,

$$\frac{2AT}{a^2}a_0,$$

where a_0 is a given function of latitude, not changing sign in passing from one hemisphere to the other. Hence, the

Total Heat gained or lost in a Year is proportional to

$$\frac{2A}{a^2}a_0 - B(\Theta_0 + 460)^3\left\{1 \pm \frac{3e\alpha_1}{\Theta_0 + 460}\cos\varpi \pm \frac{3e\beta_1}{\Theta_0 + 460}\sin\varpi\right\}. \qquad (51)$$

The secular variation of terrestrial radiation, depending on the longitude of the perihelion of the Earth's orbit, is therefore determined by the following:—

Secular Semirange of Temperature

$$= \left(\frac{3e}{\Theta_0 + 460}\right)\sqrt{(\alpha_1^2 + \beta_1^2)}; \qquad (52)$$

Retardation or Acceleration of Period from time when Midwinter or Midsummer correspond with Earth's Perihelion or Aphelion

$$= \tan^{-1}\left(\frac{\beta_1}{\alpha_1}\right). \qquad (53)$$

Cor. 1.—From equation (51) compared with (44), it appears that the *secular* retardation or acceleration is equal to the *annual* retardation or acceleration.

Cor. 2.—Lord Rosse has shown that the temperature of the Moon, under the influence of Sun-heat at her mid-day, amounts to 200° F.; and it is probable (as she has no atmosphere) that at her midnight the temperature falls to − 400° F., thus giving a diurnal range of 600° F.

As the Moon's day is 28 times longer than that of the Earth, this would

give (if the Earth had no atmosphere) a diurnal range of $\frac{600}{28} = 21°\,4'$ F.

We have no means of calculating what the annual range of temperature of the Earth would be if no atmosphere existed, and are therefore unable to apply equation (52) to calculate the amount (under these circumstances) of the secular variation depending on the longitude of the perihelion.

Prop. VIII.—*It is required to calculate the Amount of the Secular Variation in Terrestrial Climate, depending upon the Eccentricity and Perihelion Longitude of the Earth's Orbit, taking into account the Earth's Atmosphere.*

The effect of the atmosphere in cooling the temperature of its surface layer is produced mainly by convection, and in a much less degree by conduction. In either case, the effect may be supposed proportional to the difference of temperature between the surface layer and the upper layers of the atmosphere, where the convection ends, and where an equilibrium is established between the heat received directly from the Sun and that radiated into space.

We may, therefore, write the law of radiation as follows:—

$$Radiation = \alpha(\theta + a) + \beta(\theta + 460)^3, \qquad (54)$$

where the first term is the effect of the atmosphere, and *indirectly* of radiation into star space from the upper layers of the atmosphere, whose temperature is the unknown quantity a, which is reckoned positive below zero; while θ, the temperature of the surface layer, is reckoned positive above zero; so that $\theta + a$ expresses the difference of temperature between the surface layer and the upper layers, in which a heat equilibrium is established between direct Sun-heat and direct radiation.

The second term of equation (54) is the direct effect of the radiation of the non-luminous heat of the surface layer into space across the entire atmosphere; and this second term may be neglected, in comparison with the first, in consequence of the rapid absorption of non-luminous heat by the atmosphere.

We have now to sum the radiation as before, (54), writing

$$\theta = \theta_0 + \begin{matrix} a_1 \cos h, \\ b_1 \sin h, \end{matrix}$$

for the day, which gives us

$$\textit{Diurnal Radiation} = 2\pi a(\theta_0 + a). \tag{55}$$

If we assume, as before,

$$\theta_0 = \Theta_0 + \begin{matrix} a_1 \cos l, \\ \beta_1 \sin l, \end{matrix}$$

we have, for the entire year,

$$\textit{Annual Radiation} = 2\pi a \Sigma \left\{ \Theta_0 + \begin{matrix} a_1 \cos l \\ \beta_1 \sin l \end{matrix} \right\} \delta t;$$

where, as before, we have

$$l = \theta + \varpi,$$

$$\delta t = \frac{T(1-e^2)^{\frac{3}{2}}}{2\pi} \times \frac{\delta\theta}{(1+e\cos\theta)^2}.$$

Introducing these values, and summing round the whole circle, we finally obtain—

$$\textit{Annual Radiation} = 2\pi a T(1-e^2)^{\frac{3}{2}}$$

$$\times \left\{ \Theta_0 \left(1 + \frac{3e^2}{2}\right) + a \pm (a_1 \cos\varpi + \beta_1 \sin\varpi)e \right\}, \tag{56}$$

which becomes, when we neglect quantities of the order of the square of the eccentricity—

$$\textit{Annual Radiation} = 2\pi a T \{(\Theta_0 + a) \pm e(a_1 \cos\varpi + \beta_1 \sin\varpi)\}; \tag{57}$$

which gives, as before,

$$\textit{Secular Range} = 2e\sqrt{a_1^2 + \beta_1^2}; \tag{58}$$

Retardation of maximum Temperature referred to line of Apsides

$$= \tan^{-1}\left(\frac{\beta_1}{a_1}\right). \tag{59}$$

Hence we find the following values in the Northern Hemisphere:—

Lat. N.	Annual Range.*	Present Secular Range.	Maximum Secular Range.
Degrees.	Degrees, F.	Degrees, F.	Degrees, F.
0	2·2	0·037	0·185
10	4·5	0·075	0·375
20	13·2	0·220	1·100
30	24·8	0·413	2·065
40	33·0	0·550	2·750
50	44·2	0·737	3·685
60	55·3	0·922	4·610
70	59·8	0·997	4·985
80	59·1	0·985	4·925

This Table is independent of $(\Theta_0 + a)$, which varies with the latitude, and denotes the difference between the mean annual temperature of any place and the control-temperature of the upper layers of the atmosphere at that place.

The present secular range of temperature at any place is therefore *one-sixtieth* the annual range, and the maximum secular range is *one-twelfth* of the present annual range.

* The annual ranges in both Northern and Southern Hemispheres are taken from "Meteorological Researches for the use of the Coast Pilot. Part I." *United States Coast Survey* (W. Fenel) (1877).

It must be remembered, that as all places in the Northern Hemisphere are now at nearly the maximum of mean annual temperature, depending on the secular inequality, the figures in the third column represent the *lowering* of the temperature possible with the present eccentricity.

Forming a similar Table for the Southern Hemisphere, we have—

Lat., S.	Annual Range.	Present Secular Range.	Maximum Secular Range.
Deg. S.L.	Degrees, F.	Degrees, F.	Degrees, F.
0	2·2	0·037	0·185
10	7·0	0·117	0·585
20	10·5	0·175	0·875
30	13·3	0·222	1·110
40	11·8	0·197	0·985
50	8·5	0·142	0·710
60	6·5	0·108	0·540

These ranges of secular mean annual temperature are much smaller than those of the Northern Hemisphere, in consequence of the totally different conditions of radiation caused by the prevalence of water surface, and by the presence of three Gulf-streams in the Southern Hemisphere, instead of one Gulf-stream, as in the Northern.

Let us take, as an example in the Northern Hemisphere, the case of North Grinnel Land, as observed by the British Arctic Expedition of 1875–6 (lat. 81°44).

In the winter quarters of the "Alert" the maximum and minimum monthly mean temperatures were—

July, . . .	+ 38°·356 F.
March, . .	− 39 ·768 ,,
Range, .	78°·124 ,,

In the winter quarters of the "Discovery" the corresponding temperatures were—

July, . . .	+ 37°·21 F.
January, . .	− 40 ·64 ,,
Range, .	77°·85 ,,

Calculating, as before, from a range of 78° in annual temperature, we find

Maximum secular range in annual temperature in North Grinnel Land, = 6°·5 F.

As the mean annual temperature of North Grinnel Land is now − 2°·42 F. below zero (Fahrenheit), we find the maximum possible mean annual temperature of North Grinnel Land = + 0°·83, and its minimum possible mean annual temperature = − 5°·67 F.

Miocene coal-beds were found in North Grinnel Land, furnishing evidence of the climate of this locality in the middle Tertiary period. I have elsewhere* shown that the climate thus indicated was—

Least possible July Temperature, . .	63°·7 F.
,, ,, January ,, . .	21 ·0 ,,
,, ,, Mean ,, . .	42°·35 ,,

corresponding with the present climate of the southern parts of the Gulf of St. Lawrence and of the Baltic Sea.

It is clear that the secular variation of mean annual temperature cannot account for the climate of Grinnel Land in Miocene times, which had in those times an annual temperature more than 40 degrees Fahrenheit above that given by the maximum secular variation.

Let us take, as an example in the Southern Hemisphere, Kerguelen Island (lat. 50°). The Summer observations of temperature were made by

* *Lectures on Physical Geography*, pp. 315–22.

the Rev. S. J. Perry, S.J., in 1874–5, during the Transit of Venus Expedition; and the Winter observations were made in 1840 during Sir James Ross's Antarctic Expedition.*

We find from these observations—

Kerguelen Island,

February, . . .	46°·1 F.
July, ...	35 ·3 „
Range, . .	10°·8 „

Calculating as before, we find,

$$\left.\begin{array}{c}\textit{Maximum secular range in annual temperature in Kerguelen Island,}\end{array}\right\} = 0°{\cdot}900 \text{ F.}$$

The greatest possible mean annual temperature produced by the secular variation is 41°·15 F., and the least possible is 40°·25 F.

The difference between North Grinnel Land and Kerguelen Island illustrates well the totally different thermal conditions of the two hemispheres.

Prop. IX.—*It is required to find an Approximation to the Values of the Control Temperature of the Atmosphere at different Latitudes.*

The annual radiation is expressed by

$$\textit{Radiation} = B(\theta_n + a_n), \tag{60}$$

* *Report on the Meteorology of Kerguelen Island* (1879), by Rev. S. J. Perry, S.J. Published by the authority of the Meteorological Council.

where

B = a local constant;

θ_n = mean annual temperature for latitude λ_n;

a_n = mean annual control temperature for latitude λ_n.

We have the following data:—*

Latitude.	Radiation. Ice feet melted.	Mean Annual Temperature.	
		Northern Hem.	Southern Hem.
Deg. Lat.	Ice-feet.	Degrees, F.	Degrees, F.
0	100·0	80·1	80·1
10	98·6	81·0	78·7
20	94·5	77·6	74·7
30	87·9	67·6	66·7
40	79·0	56·5	57·9
50	68·4	43·4	47·8
60	56·9	29·3	35·3
70	47·4	14·4	—
80	42·9	4·5	—
90	41·5	—	—

From these data, neglecting the local variations of B, we find for the Northern Hemisphere the following approximate equations of condition:—

$$\frac{100}{98\cdot6} = \frac{80\cdot1 + a_0}{81\cdot0 + a_{10}}; \qquad (a)$$

$$\frac{98\cdot6}{94\cdot5} = \frac{81\cdot0 + a_{10}}{77\cdot6 + a_{20}}; \qquad (b)$$

* *U. S. A. Coast Survey* (Ferrel).

$$\frac{94\cdot5}{87\cdot9}=\frac{77\cdot6+a_{20}}{67\cdot6+a_{30}}; \qquad (c)$$

$$\frac{87\cdot9}{79\cdot0}=\frac{67\cdot6+a_{30}}{56\cdot5+a_{40}}; \qquad (d)$$

$$\frac{79\cdot0}{68\cdot4}=\frac{56\cdot5+a_{40}}{43\cdot4+a_{50}}; \qquad (e)$$

$$\frac{68\cdot4}{56\cdot9}=\frac{43\cdot4+a_{50}}{29\cdot3+a_{60}}; \qquad (f)$$

$$\frac{56\cdot9}{47\cdot4}=\frac{29\cdot3+a_{60}}{14\cdot4+a_{70}}; \qquad (g)$$

$$\frac{47\cdot4}{42\cdot9}=\frac{14\cdot4+a_{70}}{4\cdot5+a_{80}}. \qquad (h)$$

These equations are equivalent to the following:—

$$a_{10}=0\cdot986\,a_0-2\cdot02; \qquad (a)$$

$$a_{20}=0\cdot958\,a_{10}+0\cdot03; \qquad (b)$$

$$a_{30}=0\cdot930\,a_{20}+4\cdot58; \qquad (c)$$

$$a_{40}=0\cdot899\,a_{30}+4\cdot25; \qquad (d)$$

$$a_{50}=0\cdot866\,a_{40}+5\cdot52; \qquad (e)$$

$$a_{60}=0\cdot832\,a_{50}+6\cdot80; \qquad (f)$$

$$a_{70}=0\cdot833\,a_{60}+10\cdot00; \qquad (g)$$

$$a_{80}=0\cdot905\,a_{70}+8\cdot53. \qquad (h)$$

In these equations there is one more unknown quantity than there are

equations: we can proceed, therefore, only by hypothesis, and obtain limits by which we form the following Table.

If a_{80} be given, then we have—

	a_{80}	a_{70}	a_{60}	a_{50}	a_{40}	a_{30}	a_{20}	a_{10}	a_0
	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F,	Deg. F.	Deg. F.	Deg. F.	Deg. F.
1	60	56·9	56·3	59·5	62·4	64·7	64·7	67·4	70·4
2	50	45·8	43·0	43·5	43·9	44·1	42·5	44·3	47·0
3	40	34·8	29·8	27·7	25·6	23·7	20·6	21·4	23·7
4	30	23·7	16·4	11·5	6·9	2·9	− 1·8	− 1·9	+ 0·1
5	20	12·7	3·2	− 4·3	−11·3	−17·3	−23·5	−24·6	−22·9
6	10	1·6	−10·0	−20·2	−29·7	−37·7	−45·5	−47·5	−46·1
7	0	− 9·4	−23·3	−36·2	−48·2	−62·8	−72·5	−74·6	−73·6

All that we can say, on inspection of the foregoing Table, is, that probably the control temperature (a) is less than 30° F. below zero at 80° N. latitude: for this temperature should be lower as the latitude increases, which is not the case for the suppositions

$$a_{80} = 60° \text{ F.}, 50° \text{ F.}, 40° \text{ F.},$$

but is so for lesser values of a_{80}.

VI.—*New Researches on Sun-heat and Terrestrial Radiation, and on Geological Climates. By the* Rev. Samuel Haughton, M.D. Dubl.; D.C.L. Oxon.; LL.D. Cantab.

[Read, April 25th, 1881.]

PART II.

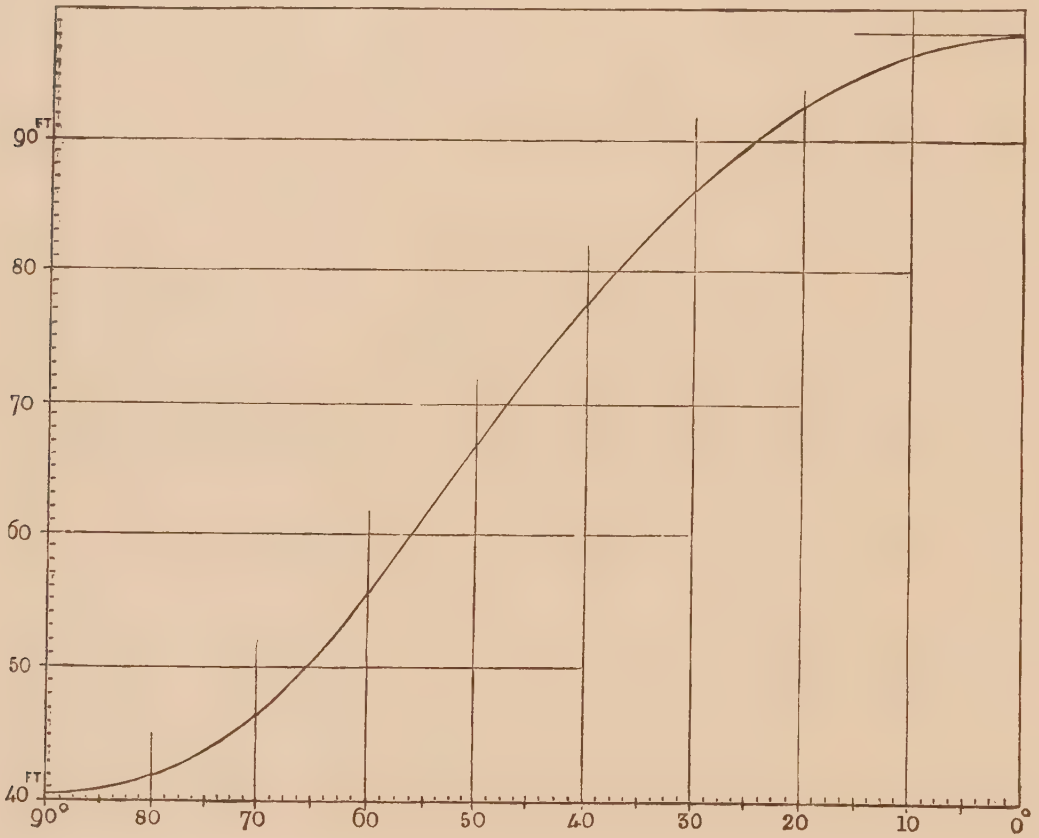
Prop. X.—*It is required to calculate the Effects of the Gulf-stream upon the Climates of the North Atlantic and Arctic Regions.*

The following Table shows the mean annual temperature, for all longitudes, of the several latitudes in the Northern and Southern Hemispheres:

Lat. N.	Annual Temperature.	Lat. S.	Annual Temperature.
Deg. N.L.	Degrees, F.	Deg. S.L.	Degrees, F.
0	80·1	0	80·1
10	81·0	10	78·7
20	77·6	20	74·4
30	67·6	30	66·7
40	56·5	40	57·9
50	43·4	50	47·8
60	29·3	60	35·3
70	14·4	—	—
80	4·5	—	—

From this it appears that the Northern Hemisphere is warmer than the Southern from lat. 0° to lat. 30°, and that it is colder than the Southern

from lat. 40° to lat. 60°.* The higher temperature of the Southern Hemisphere in the temperate latitudes is explained by the existence of three Gulf-streams in that hemisphere, while there is only one in the North Atlantic, and a partial one through Behring's Straits, in the Northern Hemisphere.



If we plot, to scale, the Sun-heats given in Table (p. 61), we obtain the accompanying diagram, in which the abscissas are degrees of latitude, and

* In point of fact, the latitude at which the mean annual temperature, at all longitudes, is the freezing point of water is 58° 51′ in the Northern Hemisphere, and 62° 41′ in the Southern Hemisphere; or, in other words, the latitude of mean temperature of 32° F. lies nearer the Pole in the Southern Hemisphere than in the Northern by 3° 50′, or 230 geographical miles. This makes a very sensible difference between the two hemispheres, in favour of the Southern.

the ordinates are Sun-heats expressed in feet-thickness of ice, on the supposition that the Sun-heat at the Equator is capable of melting in one year 97·8 feet thick of ice at 32° F.* It will be noticed that this curve reaches a maximum at the Equator and a minimum at the Poles, and has a point of inflection between 60° and 70° at the Arctic Circle, where its curvature changes.†

If we make use of Ferrel's Tables‡ of temperature for each parallel of latitude affected by the Gulf-stream in the North Atlantic, we find the following results:—

Mean Annual Temperatures.

Lat. N.	Range of Longitude influenced by Gulf-stream.	Mean Temperature of Air above Gulf-stream.	Mean Temperature of all other Longitudes.
Deg. N.L.	Degrees, Longitude.	Degrees, F.	Degrees, F.
40	0 to 50 W.	61·60	55·68
50	10 E. ,, 30 W.	52·00	42·01
60	20 E. ,, 20 W.	44·60	26·83
70	20 E. ,, 10 W.	30·00	11·07
80	70 E. ,, 10 W.	11·22	2·26

The last column shows the mean annual temperature to which the

* Vide *Six Lectures on Physical Geography*, pp. 127, 8. The calculation takes account of the loss of Sun-heat, caused by atmospheric absorption, when the Sun is in the zenith; but the atmosphere is neglected when the Sun has any other position. It is more exact to say that the Sun-heat received by the outer layer of the Earth's atmosphere at the Equator, in one year, is sufficient to melt a thickness of ice equal to 126·63 feet.

† The mean annual temperatures given in the preceding Table (p. 77), when plotted, show the same kind of curve.

‡ *United States Coast Survey.* "Meteorological Researches for the use of the Coast Pilot. Part I." By William Ferrel, M.A. 1877.

climates affected by the Gulf-stream would fall if the Gulf-stream were to cease, and the differences are shown in the following Table:—

Local and General Fall of Temperature occasioned by the supposed cessation of the Gulf-stream. Mean Annual Temperatures.

Lat. N.	Local Fall at Gulf-stream Longitudes.	General Fall at all other Longitudes.
Deg. N.L.	Degrees, F.	Degrees, F.
40	5·92	0·82
50	9·99	1·39
60	17·77	2·47
70	18·93	3·33
80	8·96	2·24

If, instead of tabulating the mean annual temperatures, we tabulate the mean July and January temperatures, we obtain the following results :—

Mean July Temperatures.

Lat. N.	Temperature at Gulf-stream Longitudes.	Temperature at all other Longitudes.	Diff.
Deg. N.L.	Degrees, F.	Degrees, F.	Degrees, F.
40	70·00	73·40	− 3·40
50	63·80	65·77	− 1·97
60	57·40	56·94	+ 0·46
70	44·75	44·24	+ 0·51
80	32·78	34·54	− 1·76
Sum, .	268·73 F.	274·89 F.	− 1·23 F.

From this Table we see that the Gulf-stream adds nothing to the July

temperatures of the localities affected by it, but rather, on the whole, has the effect of slightly diminishing the Summer heat. This fact will be of extreme importance when we come to discuss the question of the Tertiary Climates of the Arctic Regions.

Mean January Temperatures:—

Lat. N.	Temperature at Gulf-stream Longitudes.	Temperature at all other Longitudes.	Diff.
Deg. N. L.	Degrees, F.	Degrees, F.	Degrees, F.
30*	63·43	53·21	+ 10·22
40	52·00	37·93	+ 14·07
50	40·00	18·28	+ 21·72
60	32·80	− 3·44	+ 36·24
70	20·75	− 20·03	+ 40·78
80	− 10·44	− 29·85	+ 19·41
Sum, .	+ 199·34 F.	+ 56·10 F.	+ 23·87 F.

From these Tables it is evident that the action of the Gulf-stream upon the climates of high latitudes consists simply in raising the Winter heat, while the Summer heat remains unaffected, and the mean annual temperature is raised by about half the amount of rise in the January temperature.

The general climatal effect of the Gulf-stream is therefore to make the annual range of temperature less† (the climate more insular); but it has no effect whatever upon Summer heat, or upon the fruiting of plants and trees that require a given July temperature for reproduction.

These effects, as the Table shows, reach a maximum somewhere about 70° N. lat.

* Longitudes 10° W. to 70° W. are the Gulf-stream longitudes for 30° N. lat.

† This effect also diminishes the range of secular variation of temperature, depending on the eccentricity and perihelion longitude of the Earth's orbit.

The two following Tables show the effect that would be produced upon the mean July and January temperatures, at all longitudes, by a supposed withdrawal of the Gulf-stream :—

Mean July Temperatures at all Longitudes.

Lat. N.	With Gulf-stream.	Without Gulf-stream.	Diff.
Deg. N.L.	Degrees, F.	Degrees, F.	Degrees, F.
40	73·0	73·4	− 0·4
50	65·5	65·8	− 0·3
60	57·0	56·9	+ 0·1
70	44·3	44·2	+ 0·1
80	34·1	34·5	− 0·4
		Mean, ...	− 0°·18 F.

This Table proves that the withdrawal of the Gulf-stream would actually raise (by a small quantity) the mean July temperatures of the Northern Hemisphere; and that the ripening of seeds and fruits depends on Sun-heat and latitude, only.

Mean January Temperatures at all Longitudes.

Lat. N.	With Gulf-stream.	Without Gulf-stream.	Diff.
Deg. N.L.	Degrees, F.	Degrees, F.	Degrees, F.
40	40·0	37·9	+ 2·1
50	21·3	18·3	+ 3·0
60	1·7	− 3·4	+ 5·1
70	− 15·5	− 20·0	+ 4·5
80	− 25·0	− 29·8	+ 4·8

Prop. XI.—*It is required to calculate the effects of the Kuro-Siwo (Japan current) upon Climates in the North Pacific, and its effect upon the Climates of High Latitudes if it were admitted to the Arctic Ocean through Behring's Straits, widened and deepened.*

Following the same method that I have used for the Gulf-stream, I find the effects of the *Kuro-Siwo* in the North Pacific to be as follows :—

North Pacific Mean July Temperatures.

Lat. N.	Longitudes influenced by *Kuro-Siwo.*	Mean Temp. of *Kuro-Siwo* Longitudes.	Mean Temp. of all other Longitudes.	Diff.
Deg. N. L.	Degrees, Longitude.	Degrees, F.	Degrees, F.	Degrees, F.
40	130 W. to 180 W.	63·33	74·93	− 11·60
50	140 W. ,, 180 W.	58·00	66·71	− 8·71
60	140 W. ,, 170 E.	52·33	57·93	− 5·60
70*	120 W. ,, 150 W.	48·50	43·84	+ 4·66

This Table shows that the Summer effect of the *Kuro-Siwo* upon the North Pacific is even less than the Summer effect of the *Gulf-stream* upon the North Atlantic. The reason of this is, that although the *Kuro-Siwo* is a much larger current than the *Gulf-stream*, it is required to heat a much larger area, for the North Pacific is much larger than the North Atlantic.

* This represents the effect of the Kuro-Siwo which enters Behring's Straits in Summer, and extends eastward as far as Bank's Land, but is unable to enter in Winter.

The effects produced in Winter by the *Kuro-Siwo* are shown in the following Table:—

North Pacific Mean January Temperatures.

Lat. N.	Longitudes influenced by *Kuro-Siwo*.	Mean Temp. of *Kuro-Siwo* Longitudes.	Mean Temp. of all other Longitudes.	Diff.
Deg. N. L.	Degrees, Longitude.	Degrees, F.	Degrees, F.	Degrees, F.
30	120 W. to 160 E.	57·89	54·30	+ 3·59
40	110 W. ,, 170 E.	48·00	37·33	+ 10·67
50	110 W. ,, 160 E.	34·80	16·11	+ 18·69
60	130 W. ,, 170 E.	10·43	− 0·59	+ 11·02
70	*Kuro-Siwo* produces no effect.			

If we bring together the January effects of the *Gulf-stream* in the North Atlantic, and of the *Kuro-Siwo* in the North Pacific, we shall see the difference between them most clearly:—

Effects of Gulf-stream and Kuro-Siwo upon January Temperatures.

Lat. N.	Gulf-stream Excess.	*Kuro-Siwo* Excess.	Diff.
Deg. N. L.	Degrees, F.	Degrees, F.	Degrees, F.
30	+ 10·22	+ 3·59	+ 6·63
40	+ 14·07	+ 10·67	+ 3·40
50	+ 21·72	+ 18·69	+ 3·03
60	+ 37·04	+ 11·02	+ 26·02
70	+ 40·78	nil.	+ 40·78
80	+ 19·41	nil.	+ 19·41

The following considerations help to explain the differences produced

in the North Atlantic and North Pacific by their respective systems of Ocean circulation :—

1. The Ocean Currents at the Equator and between the Tropics are caused by the Trade Winds.

2. The Trade Winds are caused by the Equatorial evaporation and subsequent precipitation of vapour as rain, and the force of the Trade Winds is proportional to the rate of evaporation.

Combining these propositions, we find that the volume of the Equatorial Current will be proportional to the Equatorial breadth of the Ocean and to the rate of evaporation jointly.

The following Tables show the mean annual temperatures of the Tropical latitudes of the North Atlantic and Pacific Oceans :—

North Atlantic Ocean.

Latitude.	Longitudes.	Mean Annual Temperature.
Deg. N. L.	Degrees, Longitude.	Degrees, F.
0	10 E. to 50 W.	79·86
10	20 W. ,, 60 W.	80·40
20	20 W. ,, 100 W.	77·89
	Mean, . .	79·38 F.

North Pacific Ocean.

Latitude.	Longitudes.	Mean Annual Temperature.
Deg. N. L.	Degrees, Longitude.	Degrees, F.
0	80 W. to 120 E.	79·08
10	90 W. ,, 110 E.	78·77
20	110 W. ,, 110 E.	74·64
	Mean, . .	77·50 F.

The ratio of the mean breadths of the two oceans, in the given lati-

tudes, is—

$$\frac{Pacific}{Atlantic} = \frac{1600}{625} = 2{\cdot}56.$$

The ratio of the vapour-tensions of the mean annual temperatures of the two oceans, in the given latitudes, is—

$$\frac{Pacific}{Atlantic} = \frac{Vapour\text{-}tension\ of\ 77°{\cdot}50\ \mathrm{F.}}{Vapour\text{-}tension\ of\ 79°{\cdot}38\ \mathrm{F.}} = \frac{0{\cdot}947\ \mathrm{in.}}{1{\cdot}001\ \mathrm{in.}}.$$

Hence, the approximate ratio of the volumes of the Pacific and Atlantic Equatorial Currents, which produce the *Kuro-Siwo* and *Gulf-stream*, is

$$\frac{1600}{625} \times \frac{947}{1001} = 2{\cdot}422\,;$$

or, in other words, the forces producing the *Kuro-Siwo* are nearly two and a-half times greater than the forces producing the *Gulf-stream*.

To find, from the foregoing ratio of the volumes of the two ocean streams, that of their heat-producing effect, we must multiply by the excess of temperature above 32° F., or by

$$\frac{77°{\cdot}50\ \mathrm{F.} - 32°{\cdot}0\ \mathrm{F.}}{79°{\cdot}38\ \mathrm{F.} - 32°{\cdot}0\ \mathrm{F.}} = \frac{45{\cdot}50}{47{\cdot}38}\,;$$

from which we find the ratio of the effect (in melting ice) of the *Kuro-Siwo* to the *Gulf-stream*.

$$\frac{\text{Relative Heating Effect of } Kuro\text{-}Siwo}{Gulf\text{-}stream} = 2{\cdot}422 \times \frac{4550}{4738} = 2{\cdot}325.$$

In order to find the actual relative effects of the Pacific and Atlantic Ocean Currents in affecting climate at any locality, we must further take account of the relative areas over which these effects are spread. In the North Pacific, the January temperatures are raised from the 30th parallel of latitude to the 65th parallel; and, in the North Atlantic, from the 40th parallel to the 80th parallel.

I have calculated the relative areas of these surfaces, and find it to be as 44,014 to 24,511.

Hence, the absolute heating effect of the *Kuro-Siwo*, as compared with the *Gulf-stream*, will be—

$$\frac{Pacific}{Atlantic} = 2{\cdot}325 \times \frac{24511}{44014} = 1{\cdot}295.$$

From these calculations it follows that, although the volume of the *Kuro-Siwo* is 2·42 times greater than that of the *Gulf-stream*, its heating effect is only 1·29 times greater.

We are now in a position to calculate, numerically, the effect upon climate that would be produced by widening and deepening Behring's Strait. I shall suppose it widened and deepened from the Kamtschatka mountain range on the west to the mouth of the Mackenzie river on the east, by the submersion of the Tchukchi land, and of Aliaska and Alaska.

Parallel of 60° *N. January Temperature.*

In the North Atlantic, the effect of the Gulf-stream is shown by its raising the temperature of January from long. 30 W. to long. 10 E. to a mean of + 32°·8 F., whereas the mean temperature of this parallel at all longitudes is only + 1°·7. The July temperature remains unaffected.

If we now suppose the *Kuro-Siwo* admitted through the widened Behring's Strait to produce a similar effect in the proportion of 129 to 100, we obtain the following results.

The present mean January temperatures at Behring's Strait are as follows at 60° N. :—

Long.	170 E.	+ 12° F.
,,	180 ,, ...	− 26 ,,
,,	170 W.	− 24 ,,
,,	160 ,, ...	− 22 ,,
,,	150 ,, ...	− 23 ,,
,,	140 ,, ...	− 24 ,,
,,	130 ,, ...	− 26 ,,
	Mean, . .	− 19°·00 F.

As stated above, the effect of the Gulf-stream in the North Atlantic is

to raise the temperature of January from $+1°{\cdot}7$ F. to $+32°{\cdot}8$ F. through 40° of longitude affected by it. The effect of the *Kuro-Siwo*, admitted through Behring's Strait, may therefore be measured by a corresponding rise of temperature through

$$40 \times 1{\cdot}29 = 51°{\cdot}6 \text{ of longitude.}$$

This would produce a mean January temperature, at all longitudes, equal to

$$\frac{32{\cdot}8 \times 51{\cdot}6 + 1{\cdot}7 \times 308{\cdot}4}{360} = 6°{\cdot}16 \text{ F.}$$

This raising of the January temperature at Behring's Strait from $-19°$ F. to $+32°{\cdot}8$ F. (or through $51°{\cdot}8$ F.) would, of course, produce in the longitudes affected by it an important effect in saving from destruction plants and trees which would perish at $-19°{\cdot}0$ F. in Winter, but would give no benefit whatever to plants requiring a given July temperature to ripen their seeds. Its effect at all longitudes is to raise the January temperature through $4°{\cdot}46$ F., and the mean annual temperature through $2°{\cdot}23$ F.

Parallel of 70° *N. January Temperature.*

The January temperatures in the North Atlantic, at 70° lat., are raised by the *Gulf-stream* from long. 10° W. to long. 20° E. to a mean of $+20°{\cdot}75$ F., instead of $-15°{\cdot}5$ F. at all longitudes, the July temperatures remaining unaffected.

The corresponding effects at Behring's Strait (widened and deepened) would be, assuming, as before, the proportion of 129 to 100 for the relative thermal effects of the *Kuro-Siwo* and *Gulf-stream*.

Present mean January temperatures at Behring's Strait, longitude at 70° N. lat.:—

Long.	160° W.	$-22°{\cdot}0$ F.
,,	150 ,,	$-23{\cdot}0$,,
,,	140 ,,	$-24{\cdot}0$,,
,,	130 ,,	$-26{\cdot}0$,,
,,	120 ,,	$-28{\cdot}0$,,
	Mean,	$-24°{\cdot}6$ F.

Calculating, as before, the effect of the *Kuro Siwo* (admitted through Behring's Strait) upon all longitudes, I find that it would raise the January temperature through

$$30 \times 1{\cdot}29 = 38°{\cdot}7 \text{ of longitude}$$

to the temperature of $+ 20°{\cdot}75$ instead of $- 24°{\cdot}6$ F., which is the present temperature of the longitudes affected; and that the consequent mean January temperature at all longitudes would be

$$\frac{20{\cdot}75 \times 38{\cdot}7 - 15{\cdot}5 \times 321{\cdot}3}{360} = - 11°{\cdot}53.$$

The January rise of temperature at all longitudes is therefore $3°{\cdot}97$ F., and the mean annual rise in temperature $1°{\cdot}99$ F.

This alteration would confer little benefit upon plant life at that high latitude.

Parallel of 80° *N. Lat. January Temperature.*

The January temperatures in the North Atlantic, at lat. 80°, are raised by the *Gulf-stream* from long. 0° to long. 60° E. from $- 25°{\cdot}0$ F. to $- 10°{\cdot}4$ F.; the July temperatures remaining unaffected. The corresponding effects of the *Kuro-Siwo* at Behring's Strait (widened and deepened) would be as follows, on the same supposition as before, as to the relative thermal effects of the ocean streams.

Present mean January temperatures at Behring's Strait at 80° lat. :—

Long.	170° E.	. . .	$- 33°{\cdot}0$ F.
,,	180 ,,	. . .	$- 33{\cdot}0$,,
,,	170 W.	. . .	$- 32{\cdot}0$,,
,,	160 ,,	. . .	$- 32{\cdot}0$,,
,,	150 ,,	. . .	$- 33{\cdot}0$,,
,,	140 ,,	. . .	$- 34{\cdot}0$,,
,,	130 ,,	. . .	$- 35{\cdot}0$,,
,,	120 ,,	. . .	$- 37{\cdot}0$,,
,,	110 ,,	. . .	$- 39{\cdot}0$,,
		Mean, . .	$- 34°{\cdot}22$ F.

Calculating, as before, the effect of the *Kuro-Siwo* (admitted through Behring's Strait), I find that it would raise the mean January temperature from − 34°·22 F. to − 10°·44 F. through

$$60 \times 1{\cdot}29 = 77^{\circ}{\cdot}4 \text{ of longitude}$$

affected by it. This gives, for the consequent January temperature at all longitudes—

$$\frac{-10{\cdot}44 \times 77{\cdot}4 - 25{\cdot}0 \times 282{\cdot}6}{360} = -21^{\circ}{\cdot}87 \text{ F.}$$

The January rise of temperature at all longitudes is, therefore, 3°·14 F., and the mean annual rise in temperature is 1°·57 F.

Placing all these results together, we obtain the following effect upon the January temperatures of the Arctic Regions, produced by the admission of the *Kuro-Siwo* through Behring's Strait:—

Local Effect.				General Effect.		
Lat.	Temp. before.	Temp. after.	Diff.	Temp. before.	Temp. after.	Diff.
Deg. L.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
60	− 19·0	+ 32·8	51·8	+ 1·7	+ 6·16	4·46
70	− 24·6	+ 20·75	45·35	− 15·5	− 11·53	3·97
80	− 34·2	− 10·44	23·76	− 25·0	− 21·87	3·13

As the July temperatures remain unaffected all through, zoologists and botanists can readily estimate the trifling effects of this change of climate upon animal and plant life.

We have hitherto considered the *direct* effects of tepid Ocean Currents, like the *Gulf-stream* and *Kuro-Siwo*, if admitted into the Arctic Ocean, and have found that they produce no effect whatever upon the Summer temperature of the higher latitudes, although they unquestionably benefit the Winter temperatures of those latitudes.

We must now examine the *indirect* effects of the admission of these tepid ocean currents, which are, perhaps, of more serious importance to the welfare of plants and animals.

When an ocean current, moving from south to north, obtains admission to the Arctic Ocean it produces, necessarily, on Hydro-dynamical principles, an equal and opposite counter current moving from north to south. The tepid water current is forced by the rotation of the Earth to shift its direction continually to the *right*, and thus it happens that the *Gulf-stream* is pressed upon the western shores of Europe and Spitzbergen, and benefits those localities in Winter. On the other hand, the cold counter current, returning through Baffin's Bay and along the east coast of Greenland, is also forced by the Earth's rotation to keep to its *right*, and so is pressed upon the coast of Labrador and the east coast of North America as far south as Cape Cod. This return, or counter current, known as the *Labrador Current*, and others, exercises an influence upon climate the opposite of that of the Gulf-stream, and of such a kind as to render it very doubtful whether the *Gulf-stream* is a real benefit to the climate of the whole Globe or not.

While the *Gulf-stream raises* the *January* temperature of all places visited by it, the *Labrador* or counter current *lowers* the *July* temperature of all places affected by it. This is readily shown by the following figures :—

July Temperatures, North Atlantic.

Lat. N.	Longitudes affected by Labrador Current.	All other Longitudes.	Diff.*
Deg. N. L.	Degrees, F.	Degrees, F.	Degrees, F.
40	70·0	73·0	3·0
50	60·0	65·5	5·5
60	47·0	57·0	10·0
70	38·0	44·3	6·3

Similar, though lesser, effects are to be found on the east coast of Asia,

* These differences would be still greater if we were to leave out of account the longitudes affected by the higher temperature of the Gulf-stream.

caused by the counter cold current issuing from Behring's Strait, and pressing to the right along that coast.

Remembering that the *Gulf-stream* is helpless to increase the July temperatures, upon which the reproduction of plants is chiefly dependent, we may confidently assert that the serious lowering of July temperature, caused *indirectly* by means of its counter current through the agency of the *Gulf-stream*, has a more important influence upon the geographical distribution of plants than its direct influence in mitigating the severity of the Winter months.

If we imagine the *Kuro-Siwo* admitted into the Arctic Ocean by a broad, deep channel to the east of Kamtschatka, we must bear in mind the fact already proved, that although its thermal effect is only one and a-quarter times that of the *Gulf-stream*, its actual volume is two and a-half times as much; and, by the laws of hydrodynamics, the counter cold current moving south-west produced by it will be two and a-half times greater than the *Labrador* current. Supposing it to be a little less cold, and discounting the counter current already issuing from Behring's Strait, we cannot estimate the damaging effect of the *Counter Kuro-Siwo* current at less than double that of the Atlantic *Labrador* current. What effect will this produce upon the climate of eastern Asia?

When we remember that the cold counter currents of the Gulf-stream are able to cover Greenland with perpetual ice, and bring the iceberg limit down to 60° N., it is not unreasonable to suppose that the North Pacific counter currents, caused by the admission of the *Kuro-Siwo* through Behring's Strait, having at least double the volume of the Atlantic counter currents, would bring the iceberg limit in eastern Asia as far south as Pekin* (40° lat.), and cover the valley of the Amoor and the northern Japanese islands with a coating of glacial ice.†

* If the Labrador counter current were twice its present volume, it is highly probable (if North America were at the same time depressed a few hundred feet), that the limit of the edge of ice in Spring would reach the latitude of New York, and that all the glacial phenomena of that Continent would be reproduced.

† The absence of all traces of glaciation, or of ice transport of boulders in the Altai mountain ranges, and indeed throughout Eastern Siberia, renders it highly probable that Behring's Strait was never widened and deepened, though it has often been dry land.

The destruction of vegetation caused by the *Kuro-Siwo* counter currents would be far more than equivalent to the small benefits obtained in January temperatures from its admission to the Arctic Regions.

Prop. XII.—*It is required to calculate the effects upon Climate of an Ocean Current, admitted to the Arctic Ocean from the Indian Ocean across the Caspian and Aral Sea depression, to the east of the Ural Mountain Chain and Nova Zembla.*

This Ocean Current has been suggested by Mr. Alfred R. Wallace as a probable cause of recent changes in climate, and is highly probable, on geological grounds.

The mean width of the Indian Ocean in tropical latitudes, as compared with that of the Atlantic Ocean, is as 520 to 625. The mean annual temperatures of the air in the Indian Ocean are—

N. Indian Ocean,

Latitude.	Longitudes.	Mean Annual Temperature.
Deg. N.L.	Degrees, Longitude.	Degrees, F.
0	40 E. to 100 E.	80·6
10	50 E. ,, 100 E.	81·5
20	60 E. ,, 90 E.	79·5
	Mean, . . .	80·53 F.

The vapour-tension corresponding to this temperatnre is 1·035 inches.

Hence, following the same method as before, we find the ratio of volumes of

$$\frac{\textit{N. Indian Ocean Current}}{\textit{N. Atlantic Ocean Current}} = \frac{520}{625} \times \frac{1001}{1035} = 0{\cdot}805.$$

The relative thermal (ice-melting) effects of the two currents will be

found by multiplying by the excess of temperatures above the freezing point, or

$$\frac{80°{\cdot}53 \text{ F.} - 32°{\cdot}0 \text{ F.}}{79°{\cdot}38 \text{ F.} - 32°{\cdot}0 \text{ F.}} = \frac{48{\cdot}53}{47{\cdot}38}.$$

This gives, finally, for the ratio of the thermal effects—

$$\frac{\textit{N. Indian Ocean}}{\textit{N. Atlantic Ocean}} = 0{\cdot}805 \times \frac{48{\cdot}53}{47{\cdot}38} = 0{\cdot}824.$$

Hence we may conclude that the supposed N. Indian Ocean Current, both in volume and thermal effect, would amount to about four-fifths of the present Gulf-stream, whereas the North Pacific Ocean Current would have five-fourths of the thermal effect of the Gulf-stream, and two and a-half times its volume, which latter determines the amount and volume of the counter current of cold water.

If we calculate from Ferrel's Tables, as before, the effect of the new N. Indian Ocean Current, reckoned as four-fifths of the Gulf-stream, we find as follows:—

Latitude 60°.—It will raise the January temperature from 70° E. long. to 102° E. long. from − 10°·0 F. to 32°·8 F., which is equivalent to a rise at all longitudes from + 6°·16 F. to + 8°·53 F.

Latitude 70°.—It will raise the January temperature from 80° E. long. to 104° E. long. from − 18°·33 F. to 20°·75 F., which is equivalent to a rise at all longitudes from − 11°·53 F. to − 9°·35 F.

Latitude 80°.—It will raise the January temperature from 90° E. long. to 130° E. long. from − 27°·4 F. to − 10°·44 F., which is equivalent to a rise at all longitudes from − 21°·87 F. to − 20°·3 F.

If we bring together, into one point of view, all the preceding results, we find the following changes of Winter climate produced in the Arctic

Regions by the successive introduction of the *Gulf-stream*, the *Kuro-Siwo* (North Pacific Gulf-stream), and the North Indian Ocean Stream :—

(A.)—*Temperatures before admission of the Gulf-stream.*

Latitude.	July.	Mean.	January.	Range.
Degrees.	Degrees, F.	Degrees, F.	Degrees, F.	Degrees, F.
60	57·0	26·80	− 3·4	60·4
70	44·3	12·15	− 20·0	64·3
80	34·1	2·15	− 29·8	63·9

(B.)—*Present Temperatures.*

Latitude.	July.	Mean.	January.	Range.
Degrees.	Degrees, F.	Degrees, F.	Degrees, F.	Degrees, F.
60	57·0	29·3	1·7	58·7
70	44·3	14·4	− 15·5	59·8
80	34·1	4·5	− 25·0	59·1

(C.)—*Temperatures after opening Behring's Strait.*

Latitude.	July.	Mean.	January.	Range.
Degrees.	Degrees, F.	Degrees, F.	Degrees, F.	Degrees, F.
60	57·0	31·58	6·16	50·84
70	44·3	16·38	− 11·53	55·83
80	34·1	6·11	− 21·87	55·97

(D.)—*Temperatures after admitting the N. Indian Ocean Stream, to the east of the Ural Chain, through the Caspian Sea depression.*

Latitude.	July.	Mean.	January.	Range.*
Degrees.	Degrees, F.	Degrees, F.	Degrees, F.	Degrees, F.
60	57·0	32·76†	8·53	48·47
70	44·3	17·47	− 9·35	53·65
80	34·1	6·9	− 20·3	54·4

After all the tepid Ocean Streams are admitted, it is plain that the Arctic Regions would still remain very uncomfortable quarters for either plants or animals. Further, if the admission of the N. Indian Ocean Current through the Caspian were accompanied by a depression of Northern Europe through some hundred feet, its counter current would act under most favourable circumstances for lowering the July temperature of Europe, and might even produce all the known glacial phenomena of Scandinavia, the British Islands, Switzerland, and the Pyrenees.

Cor.—The magnitude of a glacier, *cæteris paribus*, depends upon that of the snow field in which it takes its origin; and any depression of the line of perpetual snow will increase the magnitude of the snow field and glaciers.

The height of the line of perpetual snow depends upon two factors only:—1. The temperature of the Summer months (July); 2. The supply of aqueous vapour to form the snow.

This fact is well illustrated by the following Table, which is copied

* The range is lessened by the admission of the Gulf-streams, and therefore the secular inequality of climate is also lessened.

† The present mean annual temperature of 60° N. lat. is 29°·3 F., and of 60° S. lat. is 35°·3 F.; so that, after all the Gulf-streams are admitted, the Northern Hemisphere will remain worse off than the Southern.

from a Paper by Mr. Joseph J. Murphy, read in 1875 before the Belfast Natural History and Philosophical Society, and is constructed on the principle (tolerably near the truth) that the temperature of the hottest month in the year decreases in ascending at the rate of 1° F. for every 300 feet:—

	Temperature of hottest month at sea-level.	Height of 32° F. in hottest month.	Height of snow-line.
Pyrenees, ...	74·5	12,750	9,300
Caucasus, ...	77·0	13,500	10,300
Mont Blanc, ...	72·5	12,150	9,000
Bernese Alps, ...	72·5	12,150	8,800
Scandinavian Fjelde, 61°43′ N., .	59·0	8,100	5,500
Mageroe, Norway, extreme North,	45·5	4,050	2,160
Himalaya, about 31° N., *north side*,	83·75	15,525	16,620
Himalaya, about 31° N., *south side*,	83·75	15,525	12,980
Andes, near Quito, ...	79·25	14,175	15,795
Do. 18° N., ...	81·5	14,850	14,772
Do. near Valparaiso, ...	68·0	10,800	12,780
Do. 37°40′ S., ...	63·5	9,450	7,960
Straits of Magellan, ...	45·5	4,050	3,390

On this Table, Mr. Murphy remarks, as is stated in the footnote.*

* "It is evident by this Table that the snow-line rises above the line of 32° for the hottest month of the year where the snow-fall is small, and sinks below it where the snow-fall is great. In the Caucasus, the Alps, and the Pyrenees, the snow-line is about three-fourths of the height of the line of 32° for the hottest month of the year; in the Fjelde of Norway, about two-thirds; in the Peruvian and Chilian Andes above, but in Patagonia and Tierra del Fuego below; above, on the north side of the Himalaya, but below on the south side. These contrasts are all to be

Professor Forbes* has expressed the opinion, founded on his study of the Norway glaciers, that a diminution of 4° F. in the temperature of the Summer months would place one-fourth of the surface of Norway within the snow-line, and pour glaciers into the head of every fiord in Western Norway. From a personal study of the Norwegian ice-fields, I am inclined to confirm this statement.

At the latitude of 60° N., the July temperatures of Greenland and Norway are—

Norway, ...	60° F.
Greenland, ...	47° ,, : Diff. = 13° F.

This represents a fall of Summer temperature more than three times as great as would be required to glaciate Norway.

At the latitude of Dublin we have—

Dublin, ...	68° F.
Nain (Labrador), . . .	48° ,, : Diff. 20° F.

This fall of temperature in July would probably be sufficient to glaciate the whole of the British Islands down to the sea level.†

explained by the difference in the amount of snow-fall, which is greater on the south than on the north side of the Himalaya, greater in Patagonia and Tierra del Fuego than in Chilé and Peru, and probably greater, at least in winter, in Norway than in Central, Southern, or Eastern Europe.

"The dependence of the height of the snow-line on summer temperature and on amount of snow-fall, to the exclusion of winter temperature, may be best shown, perhaps, by two extreme cases. The mean temperature of the Altai mountains is below freezing; yet, in consequence of the comparatively warm summer, and the small snow-fall, the height of the snow-line is about 6000 feet. On the Straits of Magellan, on the contrary, though the mean temperature is several degrees above freezing, the height of the snow-line (see Table) is little more than half as much."

* *Norway and its Glaciers*, p. 243.

† The foregoing facts and statements all point in the direction of local glaciations occurring at different times, and are totally opposed to the hypothesis of a *glacial period* affecting simultaneously one whole hemisphere, much less both hemispheres.

VII.—*Extension of the Theory of Screws to the Dynamics of any Material System.*

By Robert S. Ball, LL.D., F.R.S., Astronomer Royal for Ireland.

[Read, June 13th, 1881.]

In previous investigations the Theory of Screws has been applied to certain problems in the dynamics of *one* rigid body. I have lately become aware that this restriction may in some cases be abandoned. I propose in the present Paper to show to what extent the conceptions and methods of the Theory of Screws may be employed to elucidate certain problems in the dynamics of *any connected system* of rigid bodies.

By a system of this kind I mean an arrangement of μ rigid pieces, each piece being entirely free or constrained either by fixed obstacles or connexion with one or more of the remaining $\mu - 1$ pieces.

For convenience we may refer to each piece of the system as $1, 2, \ldots \mu$. This numbering may be quite arbitrary, and need imply no reference whatever to the mechanical connexions of the pieces.

I write only of small movements, but this includes problems of equilibrium, of small oscillations and of impulsive movements. By the *order of the freedom* of the system, I mean the number of generalized co-ordinates which would be required to specify a position which the system was capable of assuming. The order cannot be less than one (if the system be not absolutely fixed), while if each element of the system be absolutely free, the order will be 6μ.

Starting from any arbitrary position of the system, let it receive a small displacement. Each element will be displaced from its original position to

an adjacent position, compatible of course with the conditions imposed by the constraints. The displacement of each element could, however, have been effected by a twist of appropriate amplitude about a screw specially correlated to that element. The total effect of the displacement could, therefore, have been produced by giving each element a certain twist about a certain screw.

If n be the order of the freedom, a position of the system can be specified by the n co-ordinates $q_1, \ldots q_n$, and a position is of course possible for any values of $q_1, \ldots q_n$, however arbitrarily they may be selected. Everything relating to the position of the system must be capable of expression by these n co-ordinates. Let θ be the amplitude of the twist which has to be applied to the first element of the system, in order to convey it from the original position to the position which it has when the entire system is deranged to the position $q_1, \ldots q_n$. Since the quantity θ is completely defined, it must be capable of expression as a function of $q_1, \ldots q_n$; and since the quantities are small, it follows that θ must be an homogeneous function of $q_1, \ldots q_n$, for any powers of the quantities just written which exceed those of the lowest terms may be rejected as inappreciable. In a similar manner the amplitude of every other twist of the system can be expressed as a function of $q_1, \ldots q_n$. Adhering to the principle of rejecting all terms except the lowest powers of $q_1, \ldots q_n$, it must follow that all the amplitudes must either be functions of the same degree in the co-ordinates, or else those amplitudes which have a different degree are too small to be attended to. Each amplitude may thus be represented by an equation of the form

$$\theta = q_1^{\lambda} F,$$

where F is a function of the *ratios* of the co-ordinates, differing for each amplitude, and where λ is an exponent common to all the amplitudes.

We can draw from this result an inference of the greatest consequence. The system must have attained the position specified by the co-ordinates $q_1, \ldots q_n$, by passing from the initial position through certain intermediate positions. The constraints of the system permit us to choose for the intermediate positions of the system the co-ordinates $xq_1, \ldots xq_n$, where x is a

variable which increases from zero up to unity. Each value of x corresponds to one intermediate position, and thus a motion compatible with the constraints is prescribed by which the system can be conducted from the primitive position to the final position. It is not of course pretended that the route thus indicated is the only one by which the system can attain to the specified position. The routes are infinitely various, even while carefully observing the limits imposed by the constraints. Thus, for example, we might follow the route indicated by

$$x^2q_1,\ xq_2,\ \ldots\ xq_n,$$

where x^2 has replaced x as the factor of the first coefficient. As x increases from zero to unity, so the system travels from its original position to the final position, without having occupied at any intermediate stage a position common to the two routes.

Returning, however, to the route first considered, we substitute xq_1 for q_1, &c., in the expressions for the amplitudes, and thus we obtain

$$\theta = x^\lambda q_1{}^\lambda F,$$

where F, involving only the ratios of the co-ordinates, is of course independent of x. The factor x^λ is common to all the amplitudes: thus as the system moves through the various stages indicated in the continuous increase of x from zero to unity, so do each of the amplitudes proportionally increase from zero up to their final values. If we make $x^\lambda = 1 \div y$, then we see that the system can attain the position specified by the twists whose amplitudes are

$$\theta_1,\ \ldots\ \theta_\mu,$$

and that the constraints will permit this position to be attained by passing through the intermediate series of positions indicated by

$$y\theta_1,\ \ldots\ y\theta_\mu,$$

as y increases from zero to unity.

This movement is nothing else than an actual twist of each element of the body about its appropriate screw. Observe also that at each stage of

the movement the ratio of the amplitudes of the twists of any two elements is equal to their ratio in the final position.

As the result just attained is an important one, it is well to state it from a somewhat different point of view. That the system can be brought from a standard position A to another position B, by twisting each element about an appropriate screw, is an immediate consequence of Chasles' fundamental theorem, and no proof need be attempted here. What we have sought to prove is a different matter. If the displacements be of considerable dimensions, then, although the constraints will permit the system to attain the position B, and although they will usually admit that the journey from A to B can be made along various routes, yet in general we shall find that the constraints will preclude any arbitrarily-specified route. They will for instance usually preclude that most simple of all routes which is obtained by giving each element one twist about an appropriate screw. We have, however, now shown that when the position B is closely adjacent to the position A, the constraints, whatever they may be, will offer no hindrance to this simple type of movement.

It will be observed that our argument assumes not only that the position of the system indicated by the symbol B is closely adjacent to A, but also that the transition from A to B can be effected without passing through any stages which are at a finite distance from the initial stage. Contrivances are easily conceivable in which this condition is not fulfilled. Suppose, for example, a body be permitted to rotate freely round an axis in one direction, but not at all in the other direction. It might then happen that two consecutive positions of the body A and B are so related, that though the body can be brought from B to A by an infinitely small movement, yet to go from A to B would require rotation through an angle of almost 360°. I do not, however, dwell on such exceptional cases. It will generally happen that the constraints will be such as to admit of simple reversal, *i.e.* that the system which is brought from A to B along one route can conversely be restored from B to A by a simple backward motion along the same route.

Discarding the exceptions just indicated, we have ascertained that in general a series of screws can be assigned, each screw being appropriate to

an element of the body, and that the constraints will permit the elements to twist to and fro through infinitely small angles on their respective screws.

In the lowest type of freedom which the system can possess (short of absolute fixity) the freedom is of the first order, and any position of the system admits of specification by a single co-ordinate. In such a case the screw appropriate to each element is unique, and it is completely determined by the constraints both in position and in pitch. The ratio of the amplitude of each twist to the amplitudes of all the other twists is also prescribed by the constraints. The one co-ordinate which is arbitrary may be conveniently taken to be the amplitude of the twist about the first screw. To each value of this co-ordinate will correspond a possible position of the system. As the ratios of the amplitudes are all known, and as the first amplitude is given, then all the other amplitudes are known, and consequently the position assumed by every element of the system is known.

The whole series of screws and the ratios of the amplitudes thus embody a complete description of the particular route along which the system admits of displacement. The actual position of the system is found by adding to the purely graphic element which describes the *route* a metric element, to indicate the *distance* along that route through which the system has travelled. This *distance* is of course the arbitrary co-ordinate.

It will greatly facilitate our further progress to introduce a conventional process, which will clearly exhibit the determinate character of the ratios of the amplitudes in the screw series. Consider the two first screws, α_1 and α_2 of the series. Draw the cylindroid (α_1, α_2) which contains these two screws. Since α_1 and α_2 are appropriated to two different elements of the system, no real geometrical significance can be attached to the composition of the two twists on α_1 and α_2. If, however, the two twists on α_1 and α_2, *having the proper ratio of amplitudes*, were applied to a single rigid body, the twist produced is one which could have been effected by a single twist about a single screw on the cylindroid (α_1, α_2). This screw being given, the ratio of the amplitudes is determined. It is in fact equal to the ratio of the sines of the angles into which the intermediate screw divides the angle between the two given screws. In a similar manner we may conceive an intermediate screw inserted between every consecutive pair of the μ original screws.

It will be convenient to have a name which shall concisely express the entire series of μ original screws with the $\mu - 1$ intermediate screws whose function in determining the amplitudes has just been explained. We may perhaps call it a *screw-chain*. A *twist about a screw-chain* will denote a displacement of a material system, produced by twisting each element about the corresponding screw, through an amplitude whose ratio to the amplitudes on the two adjacent screws is indicated by the intermediate screws. The amplitude of the entire twist will, as already mentioned, be most conveniently expressed by the twist about the first screw of the chain. We hence have the following statement:—

The most general displacement of which a material system is capable can be produced by a twist about a screw-chain.

Given a material system of μ elements more or less connected *inter se*, or related to fixed points or supports: let it be required to ascertain the nature of the freedom which that system enjoys. The freedom is to be tested by the capacity for displacement which the system possesses. As each such displacement is a twist about a screw-chain, a complete examination of the freedom of the system will require that a trial be made to twist the system about every screw-chain in space which contains the right number of elements μ. If in the course of these trials it be found that the system cannot be twisted about any screw-chain, then the system is absolutely rigid, and has no freedom whatever. If after all trials have been made, one screw-chain, and only one, has been discovered, then the system has freedom of the first order, and we have the result thus stated:—

When any material system is limited by any constraints, so that its position can be expressed by a single co-ordinate, then the system is said to have freedom of the first order, and its possible movements are solely those which could be accomplished by twisting about one definite screw-chain.

By this method of viewing the question we secure the advantage of eliminating, as it were, the speical characters of the constraints. The essential moving parts of a steam engine, for example, have but one degree of freedom.* Each angular position of the fly-wheel necessarily involves a

* The governor balls are an exception. They have (speaking kinematically) an additional degree of freedom. There are, perhaps, other exceptions in reversing gear, &c.

definite position of all the other parts. A small angular motion of the fly-wheel necessarily involves a small displacement of all the other parts. Complicated as the mechanism may be, it is yet always possible to construct a screw-chain, a twist about which would carry each element from its original position into the position it assumes after the displacement has been effected.

Suppose that after one screw-chain has been discovered, about which the system can be twisted, the search is continued until another screw-chain is detected of which the same can be asserted. We are now able to show, without any further trials whatever, that an infinite number of other screw-chains must be in the same predicament. For, compound a twist of amplitude α' on one chain, α, with the twist of amplitude β' on the other, β. The position thus attained could have been attained by a twist about some single chain γ. As α' and β' are arbitrary, it is plain that γ can be only one of a singly infinite number of screw-chains about which twisting must be possible.

The problem which has to be considered may be enunciated in a somewhat more symmetrical manner, as follows:—

To determine the relations of three screw-chains, α, β, γ, such that if a material system be twisted with amplitudes α', β', γ', about each of these screw-chains in succession, the system will occupy the same position after the last twist which it had before the first.

This problem can be solved by the aid of the principles laid down in the *Theory of Screws* (Chap. II.). Each element of the system receives two twists about α and β; these two twists can be compounded into a single twist about a screw lying on the cylindroid defined by the two original screws. We thus have for each element a third screw and amplitude by which the required screw-chain γ and its amplitude γ' is completely determined.

A system free to twist to and fro on the chains α and β will therefore be free to twist to and fro on the chain γ. And these three chains being known, we can construct, with the greatest facility, an infinite number of other screw-chains about which the system must be also able to twist.

Let δ be a further screw-chain of the system, then the screws $\alpha_1, \beta_1, \gamma_1, \delta_1$ must be co-cylindroidal; so must $\alpha_2, \beta_2, \gamma_2, \delta_2$, &c.: we thus have μ cylindroids determined by the two first chains, and each screw of every chain

will lie upon the corresponding cylindroid. We have explained (*Screws*, p. 106) what is meant by the anharmonic ratio of four screws on a cylindroid: it is, indeed, nothing else than the anharmonic ratio of a pencil of four lines parallel to these screws. If, then, we denote the anharmonic ratio of α_1, β_1, γ_1, δ_1 by the symbol

$$[\alpha_1, \beta_1, \gamma_1, \delta_1],$$

then the first point to be proved is, that

$$[\alpha_1, \beta_1, \gamma_1, \delta_1] = [\alpha_2, \beta_2, \gamma_2, \delta_2] = \&c. = [\alpha_\mu, \beta_\mu, \gamma_\mu, \delta_\mu],$$

or that the anharmonic ratio of each group of four screws is constant.

This important theorem can be easily demonstrated by the aid of fundamental principles.

The two first chains, α and β, will be sufficient to determine the entire series of cylindroids. When the third chain, γ, is also given, the construction of additional chains can proceed by the anharmonic equality without any further reference to the ratios of the amplitudes.

It is plain that when any screw, δ_1, is chosen arbitrarily on the first cylindroid, that then δ_2, δ_3, &c., . . . δ_μ, are all determined uniquely; for a twist about δ_1 can be decomposed into twists about α_1 and β_1: the amplitudes of the twists on α_1 and β_1 determine the amplitudes on α_2 and β_2 by the known intermediate screws, and by compounding the twists on α_2 and β_2 we obtain δ_2. If δ_2 had been given, then it is easy to see that δ_1 and all the rest, δ_3, . . . δ_μ, are likewise determined. Taking, then, the two first cylindroids, we see that to any one screw on either corresponds one screw on the other. These two screws must trace out two homographic systems. Let us suppose that each screw is specified by the tangent of the angle which it makes with one of the principal screws of its cylindroid. Let θ, ϕ be the angles for two corresponding screws on the first and second cylindroids, then we must have some relation which connects $\tan\theta$ and $\tan\phi$. But this relation is to be consistent with the condition that *one* value of $\tan\theta$ is to correspond to *one* value of $\tan\phi$, and *one* value of $\tan\phi$ to *one* value of $\tan\theta$. The most general relation which fulfils this condition is,

$$a\tan\theta\tan\phi + b\tan\theta + c\tan\phi + d = 0.$$

Let θ_1, θ_2, θ_3, θ_4 be the angles of four screws on the first cylindroid, then the anharmonic ratio will be

$$\frac{\sin(\theta_4 - \theta_2)}{\sin(\theta_4 - \theta_3)} \frac{\sin(\theta_3 - \theta_1)}{\sin(\theta_2 - \theta_1)},$$

and from the relation between $\tan\theta_1$, $\tan\phi_1$, &c., it will be easily seen that this is unaltered when the angles ϕ_1, ϕ_2, &c., are substituted for θ_1, θ_2, &c.

We have, therefore, shown that the anharmonic ratio of four screws on the first cylindroid is equal to that of the four corresponding screws on the second, and so on to the last of the μ cylindroids.

As soon, therefore, as any arbitrary screw δ_1 is chosen on the first cylindroid, we can step from one cylindroid to the next, merely guided in choosing δ_2, δ_3, &c., by the anharmonic ratio which the screw chosen has with the three other screws on the same cylindroid. Any number of chains may thus be constructed with the utmost facility.

This process, however, does not indicate the amplitudes of the twists appropriate to δ_1, δ_2, δ_3, &c. One of these amplitudes may no doubt be chosen arbitrarily, but the rest are then all determined. We proceed to show how the relative values of the amplitudes is to be clearly exhibited.

The first theorem to be proved is that the screws intermediate to α_1 and α_2, to β_1 and β_2, to γ_1 and γ_2 are co-cylindroidal. This will be obvious from the circumstance that three twists can be given on the screw-chains α, β, γ, which neutralize, and that consequently the three twists on the screws α_1, β_1, γ_1 will neutralize, as will also those on α_2, β_2, γ_2. Compounded in any way, these six twists must neutralize; but we can compound α_1 and α_2 into one twist on the intermediate screw, and similarly for β_1 and β_2, and for γ_1 and γ_2. We hence see that the three twists about the three intermediate screws must neutralize, and that consequently those three intermediate screws must be co-cylindroidal.

For a mechanical system with two degrees of freedom, we thus see that in addition to the cylindroids appropriate to the primary screws of each screw-chain we have now a series of secondary cylindroids, on which will lie the intermediate screws of the system.

If δ_1 be given, then it is plain that the intermediate screw between δ_1

and δ_2, as well as all the other screws of the chain and their intermediate screws, can be uniquely determined. If, however, the intermediate screw between δ_1 and δ_2 be given, the entire chain δ is also determined, yet it is not immediately obvious that that determination is unique. We can, however, show very easily that this is generally the case.

Let δ_{12} denote the given intermediate screw, and let this belong, not only to the chain δ_1, δ_2, &c., but to another chain δ_1', δ_2', &c. We then have δ_1, δ_{12}, δ_2 co-cylindroidal, and also δ_1', δ_{12}, δ_2' co-cylindroidal. Decompose any arbitrary twist of amplitude θ on δ_{12} into twists on δ_1 and δ_2, and a twist of amplitude $-\theta$ on the same δ_{12} into twists on δ_1' and δ_2'. Then the four twists must neutralize; but the two twists on δ_1' and δ_1 compound into a twist on a screw on the first cylindroid of the system; and δ_2' and δ_2 into a twist on the second cylindroid of the system; and as these two resultant twists must be equal and opposite, it follows that they must be on the same screw, and that, therefore, the cylindroids belonging to the first and second elements of the system must have a common screw. This is, however, not generally the case; it could only arise under special circumstances, which it is now needless to refer to.

The correspondence between the intermediate cylindroids and the primary cylindroids is, therefore, homographic, as one screw on either cylindroid corresponds to one screw on each of the others.

We have now obtained a picture of the freedom of the second order, which seems to leave little to be desired on the score of geometrical completeness: stating summarily the results at which we have arrived, they are as follows:—

A material system of any kind whatever receives a small displacement. This displacement is under all circumstances a twist about a screw-chain. If the system will admit of a displacement by a twist about a second screw-chain, then twists about an infinite number of other screw-chains must also be possible. To find, in the first place, a third screw-chain, give the system a small twist about the first chain; this is to be followed by a small twist about the second chain: the position of the system thus attained could have been reached by a twist about a third screw-chain. The system must, therefore, be capable of twisting about this third screw-chain. When three

of the chains have been constructed, the process of finding the remainder is greatly simplified. Each element of the system is, in each of the three displacements just referred to, twisted about a screw. Those three screws lie on one cylindroid appropriate to the element: there are as many of these cylindroids as there are elements in the system. Between each two screws of a chain lies an intermediate screw, introduced for the purpose of defining the ratio of the amplitudes of the two screws of the chain on each side of it. In the three chains two consecutive elements will thus have three intermediate screws. These screws are co-cylindroidal. We thus have two series of cylindroids: the first of these is equal in number to the elements of the system (μ), each cylindroid corresponding to one element. The second series of cylindroids consists of one less than the entire number of elements ($\mu - 1$). Each of these cylindroids is appropriated to the intermediate screw between two consecutive elements. An entire screw-chain will consist of μ primary screws, and $\mu - 1$ intermediate screws. To form such a screw-chain it is only necessary to inscribe on each of the $2\mu - 1$ cylindroids a screw which, with the other three screws on that cylindroid, shall have a constant anharmonic ratio. Any one screw on any one of the $2\mu - 1$ cylindroids may be chosen arbitrarily; but then all the other screws of that chain are absolutely determined, as the anharmonic ratio is known. The system which is capable of twisting about two screw-chains cannot refuse to be twisted about any other screw-chain constructed in the manner just described. It may, however, refuse to be twisted about any screw-chains not so constructed; and if so, then the system has freedom of the second order.

Before extending the conception of screw-chains to the examination of the higher orders of freedom, it will be necessary to notice some extensions of the notions of homography to the higher orders of screw systems. On the cylindroid there is no difficulty whatever. We can conceive the screws on two cylindroids homographically related, just as easily as we can conceive the rays of two plane pencils. But the same idea can be extended to the higher systems of screws—the 3rd, the 4th, the 5th—while a very remarkable case is presented in the homography of two 6th systems.

We commence by an examination of the homography of a pair of 3-systems. We may refer to *Theory of Screws*, chap. xi., for an account of the

general character of a 3-system. It will be here sufficient to remark, that a 3-system is merely a collection of all the screws about which any body can twist when that body has three degrees of freedom.

The homography of two 3-systems is completely established when to each screw on one system corresponds one screw on the other system, and conversely. As the position of a screw in a 3-system can be expressed by three homogeneous co-ordinates, whereof only the ratios are significant, we can represent the screws in a 3-system by the points in a plane (see *Proceedings*, R. I. A., Vol. III., 2nd Series, p. 428). We have now two planes, one for each of the 3-systems, and the screw correspondence of which we are in search is identical with the homographic point-correspondence between the two planes.

It is well known in this case that when four points in one plane, and the four corresponding points in the other plane are given, that then the entire correspondence is established. Any fifth point in one plane being given, the fifth point corresponding thereto in the other plane can be determined. It therefore follows that when four screws on one 3-system have been indicated to be the correspondents of four given screws on the other system, that then the correspondence is completely established, and any fifth screw on one system being given, its correspondent on the other is determined. The actual construction of the pairs of corresponding screws from the pairs of corresponding points in the two planes can be conducted with the greatest simplicity.

Let a, b, c, d be four points in one plane, and let a', b', c', d' be the four corresponding points in the other plane. It is required to find a point x' in the second plane corresponding to a given point x in the first plane. Since anharmonic ratios are unaltered, we must have

$$a\,(bcdx) = a'\,(b'c'd'x'),$$

whence the ray $a'x'$ is determined; also, since

$$b\,(abcdx) = b'\,(a'c'd'x'),$$

the ray $b'x'$ is determined, and the intersection of these two rays of course determines x'. As the co-ordinates of two corresponding screws in the 3-systems are identical with those of the corresponding points x and x' in

the plane, it follows that we have completely solved the problem of the homography of two 3-systems of screws.

We are now enabled to study the small movements of any material system which has freedom of the third order. Let such a system receive any three displacements by twists about three screw-chains. It will, of course, generally happen that these three screw-chains are not connected in the manner we have previously discussed in freedom of the second order. The three screw-chains now under consideration are perfectly arbitrary; they may differ in every conceivable way, save only that the number of primary screws in each chain must of course be equal to μ, *i. e.* the number of material elements of which the system consists.

It may be convenient to speak of the screws in the different chains which relate to the same element (or in the case of the intermediate screws, the same pair of elements) as *homologous* screws. Each set of three homologous screws will define a 3-system. Compounding together any three twists on the screw-chains, we have a resultant displacement which could have been effected by a single twist about a fourth screw-chain. The first theorem to be proved is, that each screw in this screw-chain must belong to the 3-system which is defined by the three homologous screws.

As far as the primary screws are concerned this is immediately seen. Each element having been displaced by three twists about three screws, the resultant twist must belong to the same 3-system by the definition of a 3-system. Nor do the intermediate screws present much difficulty. It must be possible for appropriate twists on the four screw-chains to neutralize. Considering the first element, the four twists it receives must neutralize; so must also the four twists which the second element receives. These eight twists must therefore neutralise, however they may be compounded. Taking each chain separately, these eight twists will reduce to four twists about the four intermediate screws: these four twists must neutralize; but this is only possible if the four intermediate screws belong to a 3-system. We are thus led to four screw-chains, whereof every four homologous screws lie on a 3-system.

On each of μ primary 3-systems, and on each of $\mu - 1$ intermediate 3-systems, we have four screws inscribed. Four corresponding screws on

each of the 3-systems being given, we choose an arbitrary screw in any one of the systems. In the exercise of this choice we have two degrees of latitude; but once the choice has been made, the remainder of the screw-chain is fixed by the following theorem:—

If each set of five homologous screws of five screw-chains lies on a 3-system, and if a mechanical system be free to twist about four of these screw-chains, it will also be free to twist about the fifth, provided each set of homologous screws is homographic with every other set.

Let δ denote the fifth screw-chain. If δ_1 be chosen arbitrarily on the 3-system, then a twist about δ_1 can be decomposed into three twists on α_1, β_1, γ_1. By the intermediate screws these three twists will give the amplitudes of the twists on all the other screws of the chains α, β, γ, and each group of three homologous twists being compounded, will give the corresponding screw on the chain δ. We thus see that when δ_1 is given, δ_2, δ_3, &c., are all determinate. It is also obvious that if δ_2, or any other primary screw of the chain, were given, that then all the other screws of the chain would be determined uniquely.

If, however, it is an intermediate screw, δ_{12}, which is given, then, although the conditions are, so far as number goes, adequate to the determination of the screw-chain, it will be necessary to prove that the determination is unique. This is proved in the same manner as for freedom of the second order. If there were two screw-chains which had the same intermediate screw, then it must follow that the two primary 3-systems must have a common screw, which is not generally the case.

We have thus shown that when any one screw of the chain δ, whether primary or intermediate, is given, then all the rest of the screws of the chain are uniquely determinate. Each group of five homologous screws must therefore be homographic.

It is thus extremely easy to construct as many screw-chains as may be desired, about which a system which has freedom of the third order must be capable of twisting. It is only necessary, after four chains have been found, to inscribe an arbitrary screw on one of the 3-systems, and then to construct the corresponding screw on each of the other systems.

In choosing one screw we have two degrees of freedom: we may, for

example, move the screw chosen over the surface of a cylindroid embraced in the 3-system: the remaining screws of the screw-chain, primary and intermediate, will each and all move over the surface of a cylindroid.

If the system cannot be twisted about any screw-chain except those we have now been considering, then the system is said to have freedom of the third order. If, however, a fourth screw-chain can be found, about which the system can twist, and if that screw-chain does not belong to the doubly infinite system just described, then the system must have freedom of the fourth order.

The homologous screws in the four screw-chains about which the system can twist form each a 4-system. All the other chains which can belong to the system must consist of screws, one of which lies on each of the 4-systems.

It will facilitate the study of the homography of two 4-systems to avail of the identity of the problem of the homography of two spaces with the homography of two 4-systems. A screw in a 4-system is defined by four homogeneous co-ordinates whereof only the ratios are significant. Each screw of such a system can therefore be represented by one point in space. The homography of two spaces will be completely determined if five points, a, b, c, d, e in one space, and the five corresponding points in the other space, a', b', c', d', e' are given. For, take any point x in the first space, and let x' be the corresponding point in the second space of which the position is sought.*

* We can imagine two spaces, each wholly filled with infinitely small particles of sand. Each grain of sand in one space is numbered from one up, and so are the grains of sand in the other space. However the sand be mixed, in the two spaces there is still a point-by-point correspondence, and that correspondence is unique. Such a chaos, however, is very different from the homographic division of the two spaces. In each it is true that but one point in either corresponds to one point in the other; but in the homographic division we have the additional conception that the co-ordinates of every point in one can be expressed as continuous functions of the co-ordinates of the corresponding point in the other.

Library catalogues will yet be constructed on homographic principles. Considering only the standard books common to each library, it would be a great convenience if each book occupied the same place in every library. But it will be said that libraries are of such different shapes and sizes that this is impossible. Homographic transformation, however, evades this difficulty. Five standard books will be taken. Each librarian may put these *where he likes on his shelves*, but once these have been located, the position of every other book is determined.

Draw the pencil of four planes through ab and the four points c, d, e, x; then the equality of anharmonic ratios will enable the corresponding pencil to be drawn through a' b' and c', d', e', x', we thus have a plane $a'b'x'$ determined, in which the sought point x' must lie. Similarly, by taking two other points, ac, as the intersection of the pencil, we obtain the plane $a'c'x'$. Finally, taking ad as the intersection of the pencil, we obtain the plane $a'd'x'$. These three planes must intersect the required point x'.

It thus follows that when five screws in one 4-system, and the five corresponding screws in the other 4-system are given, then the sixth screw in one system corresponding to any sixth screw in the other is completely determined.

From the four original screw-chains we can construct a fifth by compounding any arbitrary twists about two or more of the given chains. When five chains have been determined, then, by the aid of the principle of homography, we can, with the greatest facility, construct any number.

That each set of six homologous screws is homographic with every other set can be proved, as in the other systems already discussed. With respect to the intermediate screws a different proof is, however, needed to show that when one of these screws is given the rest of the chain is uniquely determined. The proof we now give is perhaps simpler than that previously used, while it has the advantage of applying to the other cases as well. Let α, β, γ, δ be four screw-chains, and let ϵ_{12}, an intermediate screw of the chain ϵ, be given. We can decompose a twist on ϵ_{12} into components of definite amplitude on α_{12}, β_{12}, γ_{12}, δ_{12}. The first of these can be decomposed into twists on α_1 and α_2; the second on β_1 and β_2, &c. Finally, the four twists on α_1, β_1, γ_1, δ_1 can be compounded into one twist, ϵ_1, and those on α_2, β_2, γ_2, δ_2 compounded into a twist on ϵ_2. In this way it is obvious that when ϵ_{12} is given, then ϵ_1 and ϵ_2 are uniquely determined, and of course the same reasoning applies to the whole of the chain. We thus see that when any screw of the chain is known, then all the rest are uniquely determined, and therefore the principle of homography is applicable.

In the choice of one screw there are three arbitrary elements, as we may choose any screw from a given 4-system.

If one screw of the chain be moved over a 2-system, or a 3-system included in the given 4-system, then every other screw of the chain will also describe a corresponding 2-system or 3-system.

In discussing the movements of a system which has freedom of the fifth order, the analogies which have hitherto guided us appear to fail. Homographic pencils, planes, and spaces have exhibited graphically the relations of the lower degrees of freedom; but for freedom of the fifth degree these illustrations are inadequate. No real difficulty can, however, attend the extension of the principles we have been considering to the freedom of the fifth order. We can conceive that two 5-systems are homographically related, such that to each screw on the one corresponds one screw on the other, and conversely. To establish the homography of the two systems it will be necessary to know the six screws on one system which correspond to six given screws on the other: the screw in either system corresponding to any seventh screw in the other is then completely determined.

In place of the methods peculiar to the lower degrees of freedom, we shall here state the general analytical process which is of course available in the lower degrees of freedom as well.

A screw θ in a 5-system is to be specified by five co-ordinates θ_1, θ_2, θ_3, θ_4, θ_5. These co-ordinates are homogeneous; but their ratios only are concerned, so they are equivalent to four data. The five screws of reference may be any five screws of the system. Let ϕ be the screw of the second system which is to correspond to θ in the first system. The co-ordinates of ϕ may be referred to any five screws chosen in the second system. It will thus be seen that the five screws of reference for ϕ are quite different from those of θ. As one screw in each system is to correspond to one screw in the other, and conversely, it will follow that the five co-ordinates of ϕ must be capable of being expressed linearly by the five co-ordinates of θ, and we thus have equations which may be written—

$$\phi_1 = (11)\,\theta_1 + (12)\,\theta_2 + (13)\,\theta_3 + (14)\,\theta_4 + (15)\,\theta_5,$$
$$\phi_2 = (21)\,\theta_1 + (22)\,\theta_2 + (23)\,\theta_3 + (24)\,\theta_4 + (25)\,\theta_5,$$
$$\phi_3 = (32)\,\theta_1 + (32)\,\theta_2 + (33)\,\theta_3 + (34)\,\theta_4 + (35)\,\theta_5,$$
$$\phi_4 = (41)\,\theta_1 + (42)\,\theta_2 + (43)\,\theta_3 + (44)\,\theta_4 + (45)\,\theta_5,$$
$$\phi_5 = (51)\,\theta_1 + (52)\,\theta_2 + (53)\,\theta_3 + (54)\,\theta_4 + (55)\,\theta_5.$$

For the screw ϕ to be known whenever θ is given, it will be necessary to determine the various coefficients (11), (12), &c. These are to be determined from the known pairs of corresponding screws. Of these coefficients there are in all twenty-five. If we substitute the co-ordinates of one given screw θ, we have five linear equations between the co-ordinates. Of these equations, however, we can only take the ratios, for each of the co-ordinates may be affected by an arbitrary factor. Each of the given pairs of screws will thus provide four equations to aid in determining the co-efficients. Six pairs of screws being given, we have twenty-four equations between the twenty-five coefficients. These will be sufficient to determine the ratios of the coefficients which alone concern us, for a factor common to all the coefficients will not affect the ratios of the co-ordinates of the screw ϕ We thus see that by six pairs of screws the homography of two 5-systems is to be completely defined. To any seventh screw on one system corresponds a seventh screw on the other system, which can be constructed accordingly.

It will, however, be desirable at this point to introduce quite a different method of exhibiting what is known as *screw-homography*. It will not be necessary to rely merely on the analytical conceptions of the formulæ just used. We can present the subject of homography from a mechanical point of view, which is specially appropriate for the present theory. The notions now to be discussed might have been introduced at the outset. It was, however, thought advantageous to concentrate all the light that could be obtained on the subject; we therefore used the point-homography of lines, of planes, and of spaces, so long as they were applicable.

The method which we shall now adopt is founded on an extension of what is known as "parallel projections" in Statics. We may here recall the outlines of this theory, with the view of seeing by what steps it can be generalized into one adequate for our purpose.

We can easily conceive of two systems of corresponding forces in two planes. To each force in one plane will correspond one force in the other plane, and *vice versâ*. To any system of forces in one plane will correspond a system of forces in the other plane. We are also to add the condition that if one force x vanishes, the corresponding force x' will also vanish. This is indeed almost necessarily involved in the definition; for if x be zero,

then it cannot matter where it is, and hence we should have one force x' in the second plane corresponding to an indefinite force in the first plane.

The fundamental theorem which renders this correspondence of importance is thus stated:—

If a group of forces in one of the planes would equilibrate when applied to a rigid body, then the corresponding group of forces in the other plane would also equilibrate when applied to a rigid body.

Draw any triangle in each of these planes, then any force can be decomposed into three components on the three sides of the triangle. Let x, y, z be the components of such a force in the first plane, and let x', y', z' be the components of the corresponding force in the second plane; we must then have equations of the form

$$\begin{aligned} x' &= ax + by + cz, \\ y' &= a'x + b'y + c'z, \\ z' &= a''x + b''y + c''z, \end{aligned}$$

where a, b, c, &c., are constants. These equations are not to contain any terms independent of the forces, because x', y', z' must vanish when x, y, z vanish. They must, however, be linear in the components of the forces, because otherwise one force in one plane will not correspond uniquely with one force in the other. If the system of forces in the first plane equilibrate, we must have

$$\Sigma x = 0, \quad \Sigma y = 0, \quad \Sigma z = 0,$$

and from the equations just written, these involve

$$\Sigma x' = 0, \quad \Sigma y' = 0, \quad \Sigma z' = 0,$$

whence the corresponding system in the other plane must also equilibrate.

To establish the relation, it will only be necessary to know three forces in the second plane which correspond to three given forces in the first plane. We shall then have nine equations from which to determine a, b, c, &c.

It follows obviously, from the form of the equations, that the ratio of the intensity of a force to the intensity of the corresponding force is independent of those intensities, *i. e.* it depends solely upon the situation of the lines in which the forces act.

Take any four lines in one system, and let four forces, X_1, X_2, X_3, X_4, on these four lines equilibrate. It is then well known that each of these forces must be proportional to certain functions of the positions of these lines. Call these functions A_1, A_2, A_3, A_4. The four corresponding forces will be X_1', X_2', X_3', X_4', and as they must equilibrate, they must also be in the ratio of the functions A_1', A_2', A_3', A_4'.

We thus have the equations

$$\frac{X_1}{A_1}=\frac{X_2}{A_2}=\frac{X_3}{A_3}=\frac{X_4}{A_4},$$

$$\frac{X_1'}{A_1'}=\frac{X_2'}{A_2'}=\frac{X_3'}{A_3'}=\frac{X_4'}{A_4'}.$$

Now we can select the ratio of X_1 to X_1' arbitrarily: for example, let this ratio be μ; then

$$\frac{X_2}{X_2'}=\frac{A_2}{A_2'}\mu,$$

whence the ratio of X_2 to X_2' is known. Similarly the ratio of the other intensities $X_3 : X_3'$, and $X_4 : X_4'$ is known. And generally the ratio of every pair of corresponding forces will be determined.

It thus appears that four lines in one system may be chosen arbitrarily to correspond with four lines in the other system; and that one force being chosen on one of these lines in one system, the corresponding force may be chosen arbitrarily on the corresponding line in the other system. This having been done, the entire relation between the two systems is completely defined.

From the case of parallel projections in two planes it is easy to pass to the case which will serve our present purpose. Instead of the straight lines in the two planes we shall take screws in two n-systems. Instead of the forces on the lines we may take either twists or wrenches on the screws. More generally it will be better to use Plücker's word "Dyname," which may mean either a twist or wrench, or even a twist velocity. We shall thus have a Dyname in one system corresponding to a Dyname in the other.

In two n-systems of screws let us suppose that a Dyname on a screw of one system corresponds to a Dyname on a screw of the other system, and conversely. We have then all that will be required.

In the first place it can be shown that if any number of Dynames in the first system neutralize, so must also the corresponding Dynames in the second system. Take n screws of reference in one system, and also n screws of reference in the corresponding system. Let θ be the Dyname in one system which corresponds to ϕ in the other; θ can be completely resolved into component Dynames $\theta_1, \theta_2, \ldots \theta_n$ on the n screws of reference ($n = < 6$). The constituents of the corresponding Dyname $\phi_1, \ldots \phi_n$ will be found from equations of the type

$$\phi_1 = (11)\,\theta_1 + (12)\,\theta_2 \ldots + (1\,n)\,\theta_n,$$

$$\ldots\ldots\ldots\ldots$$

$$\phi_n = (n\,1)\,\theta_1 + (n\,2)\,\theta_2 \ldots + (n\,n)\,\theta_n.$$

If the Dynames θ', θ'', θ''', &c., in the first system neutralize, then

$$\Sigma\,\theta_1 = 0, \quad \Sigma\,\theta_2 = 0, \ldots \Sigma\,\theta_n = 0\,;$$

but it is obvious from the equations just written that in this case we must have

$$\Sigma\,\phi_1 = 0, \quad \Sigma\,\phi_2 = 0, \ldots \Sigma\,\phi_n = 0\,;$$

and therefore the corresponding Dynames will also neutralize.

Given n pairs of corresponding Dynames in the two systems, we then have n^2 equations adequate to determine the n^2 constants of the type (11), (12), &c. It is thus manifest that n given pairs of Dynames suffice to determine the Dyname in either system, corresponding to a given Dyname in the other. In this case of course the intensities of the two corresponding Dynames in each of the n-pairs are given.

To illustrate the distinction between this Dyname correspondence and the screw correspondence previously discussed, let us take the case of two cylindroids. We have already seen that, given three screws on one, and three corresponding screws on the other, the correspondence is then com-

pletely defined, and any fourth screw on one will have its correspondent on the other immediately pointed out by the equality of the anharmonic ratios. In the case of the Dyname correspondence, however, we only require two pairs of corresponding Dynames on the two cylindroids, in order to completely define the correspondence. A third Dyname on one cylindroid can be resolved into two Dynames on the two screws containing the given Dynames. These components will determine the components on the corresponding cylindroid, which being compounded, will give the corresponding Dyname.

It may seem strange at first sight that two pairs of Dynames establish the correspondence as well as the three pairs of screws. A pair of corresponding screws on the two cylindroids is in reality only one datum, because one screw may be chosen arbitrarily; and as the other has only one degree of freedom on the cylindroid, its specification merely gives one datum. A pair of corresponding Dynames is, however, really two data—one for the screws as before, the other for the ratio of the amplitudes. The three pairs of corresponding screws amount to three data; the two pairs of corresponding Dynames amount to four data; the additional datum in this case being for the purpose of indicating the intensity of the correspondent.

It is indeed easy to show in general that the number of pairs of Dynames required to define the correspondence is one less than the number of pairs of screws. In an n-system a screw has $n-1$ disposable co-ordinates. To define the correspondence we require $n+1$ pairs of screws. Of course those on the first system may have been chosen arbitrarily, so that the number of data required for the correspondence is $(n-1)(n+1) = n^2 - 1$. A Dyname in an n-system has n arbitrary data, viz., $n-1$ for the screw, and one for the intensity: hence when we are given n pairs of corresponding Dynames we have altogether n^2 data. We thus see that the n pairs of corresponding Dynames really amounts to one more datum than the $n+1$ pairs of corresponding screws, that one datum being of course required for the purpose of allotting the appropriate intensity to the sought Dyname.

We can then use either the n pair of Dyname correspondents or the $(n+1)$ pair of screw correspondents. We have hitherto used the latter;

we shall now use the former. In the higher orders of freedom the screw correspondence does not seem to afford so simple a means of constructing the corresponding screw as we obtain by the Dyname correspondence. In two 5-systems the correspondence is complete when we are given five Dynames in one and the corresponding five Dynames in the other. To find the Dyname X in the second system, corresponding to the given Dyname A in the first system, we proceed as follows :—Decompose A into Dynames on the five screws which contain the five given Dynames on the first system. This is always possible, and the solution is unique. These components will correspond to determinate Dynames on the five corresponding screws: these Dynames compounded together will give the required Dyname X both in intensity and position.

In the case of freedom of the fifth order we may, by trial, determine five screw-chains about which the system can be twisted. Each set of five homologous screws will determine a 5-system. We need not in this method of proceeding pay any attention to the intermediate screws: it will only be necessary to inscribe one dyname (in this case a twist) in each of the 5-systems, so that the groups of six shall be homographic, and the set of twists so found will form a displacement which the system must be capable of receiving. This is perhaps the simplest method of viewing the question.

One more illustration may be given. Suppose we have a series of planes, and three forces in each plane. We insert in one of the planes any arbitrary force, and its parallel projection can then be placed in all the other planes. Now, suppose that a mechanical system, containing as many elements as there are planes, be so circumstanced that each element is free to accept a rotation about each of the three lines of force in the plane, and that the amplitude of the rotation is proportional to the intensity of the force; it must then follow that the system will be also free to accept rotations about any other chain formed by an arbitrary force and its parallel projections.

For the sake of uniformity we may, however, enunciate the case by the aid of the screw correspondence. We find, as before, any five screw-chains which will completely define all the other movements which the system can accept. To construct the subsequent screw-chains, which are quadruply

infinite in variety, we begin by finding one by actual composition of any two or more twists about two or more of the five screw-chains. Once a sixth chain has been ascertained the construction of the rest is greatly simplified. Each group of six homologous screws lies on a 5-system. Place in each of these 5-systems another screw which, with the remaining six, form a group which is homographic with the corresponding group in each of the other 5-systems. These screws then form another chain about which the system must be free to twist.

In the choice of one screw of the system to commence with we have only one condition to attend to: the screw chosen must belong to a given 5-system. This implies merely that the chosen screw must be reciprocal to one given screw. On any arbitrary cylindroid a screw can be chosen which is reciprocal to this screw, and consequently on any cylindroid one screw can always be selected wherewith to commence a screw-chain.

In freedom of the sixth order we select at random six displacements which the system admits, and then construct the six corresponding screw-chains. The homography in this case is not between screws limited to a certain n-system, it relates to screws situated anywhere in space. It is easily shown that if to one screw in space corresponds another screw, and conversely, then the homography is completely established when we are given seven screws in one system, and the corresponding seven screws in the other. Any eighth screw in the one system will then have its correspondent in the other immediately determined.

It is of special importance in the present theory to dwell on the type of homography with which we are here concerned. If on the one hand it seems embarrassing, from the large number of screws concerned, on the other hand we are to recollect that the question is free from the complication of regarding the screws as residing on particular n-systems. Seven screws may be drawn *anywhere, and of any pitch;* seven other screws may also be chosen anywhere, and of any pitch. If these two groups be made to correspond in pairs, then any other screw being given, its corresponding screw will be completely determined. Nor is there in this correspondence any other condition, save the simple one, that to one screw of one system shall correspond one screw of the other, and conversely.

Six screw-chains having been found, a seventh is to be constructed. This being done, the construction of as many screw-chains as may be desired is immediately feasible. From the homographic relations just referred to we have appropriate to each element of the system seven homologous screws, and also between two elements we have the seven homologous intermediate screws. An eighth screw, appropriate to any element, may be drawn arbitrarily, and the corresponding screw being constructed on each of the other systems gives at once the screw-chain.

When a system has freedom of the sixth order we see that any one element may be twisted about any arbitrary chosen screw, but that the screw about which every other element twists is determined, and so are also the ratios of the amplitudes of the twists, by the aid of the intermediate screws.

Passing from the case of six degrees of freedom to the case of seven degrees, we have a somewhat remarkable departure from the phenomena shown by the lower degrees of freedom. Give to the system any seven arbitrary displacements, and construct the seven screw-chains, α, β, γ, δ, ϵ, ζ, η by twists about which those displacements could have been effected. In the construction of an eighth chain, θ, we may proceed as follows:—Choose any arbitrary screw θ_1. Decompose a twist on θ_1 into components on α_1, β_1, γ_1, δ_1, ϵ_1, ζ_1. This must be possible, because a twist about any screw can be decomposed into twists about six arbitrary screws, the only exception being when the six screws belong to an n-system, a state of things which is infinitely improbable.

The twists on α_1, . . . ζ_1, &c., determine the twists on the screw-chains α, . . . ζ, and therefore the twists on the screws α_2, . . . ζ_2, which compound into a twist on θ_2, similarly for θ_3, &c.; consequently a screw-chain of which θ_1 is the first screw, and which belongs to the system, has been constructed. This is, however, only one of a number of screw-chains belonging to the system which have θ_1 for their first screw. The twist on θ_1 might have been decomposed on the six screws, β_1, γ_1, δ_1, ϵ_1, ζ_1, η_1, and the screws θ_2, &c., found as before, but these will of course not be identical with the θ_2, &c., found previously. Or if we take the whole seven screws, α_1, . . . η_1, we can decompose a twist on θ_1 in an infinite number of ways on these seven

screws. We may, in fact, choose the amplitude of the twist on any one of the screws of reference, α_1, for example, arbitrarily, and then the amplitudes on all the rest will be determined. It thus appears that where θ_1 is given, the screw θ_2 is not determined; it is only indicated to be any screw we please of a singly infinite number. The locus of θ_2 is therefore a ruled surface; so will be the locus of θ_3, &c.: we have, in the first place, to prove that all these ruled surfaces are cylindroids.

Take three twists on θ_1, such that the arithmetic sum of their amplitudes is zero, and which consequently neutralize. Decompose the first of these into twists on α_1, β_1, γ_1, δ_1, ζ_1, η_1, the second on α_1, β_1, γ_1, δ_1, ϵ_1, η_1, and the third on α_1, β_1, γ_1, δ_1, ϵ_1, ζ_1. It is still open to make another supposition about the twists on θ_1; let us suppose that they are such as to make the two components on η_1 vanish. It must then follow that the total twists on each of the remaining six screws, viz. α_1, β_1, γ_1, δ_1, ϵ_1, ζ_1 shall vanish, for their resultant cannot otherwise be zero. All the amplitudes of the twists about the screw-chains of reference must vanish, and so must also the amplitudes of the resultant chains when computed together; but corresponding to the three different twists on θ_1, we should have three different screws for θ_2; and as the twists on these screws must neutralize each other, the three screws must be co-cylindroidal.

We can, therefore, in constructing a chain of this system, not only choose θ_1 arbitrarily, but we can then take for θ_2 any screw on a certain cylindroid: this being done, the rest of the chain is fixed, including the intermediate screws.

If the freedom be of the eighth order, then it is easily shown that the first screw of any other chain may be taken arbitrarily, and that even the second screw may be chosen arbitrarily from a 3-system. Passing on to the twelfth order of freedom, the two first screws of the chain, as well as the amplitudes of their twists, may be chosen quite arbitrarily, and the rest of the chain is fixed. In the thirteenth order of freedom we can take the two first twists arbitrarily, while the third may be chosen anywhere on a cylindroid. It will not now be difficult to trace the progress of the chain to that unrestrained freedom it will enjoy when the system has 6μ degrees of freedom, when it is able to accept any displacement whatever. In

the last stage, prior to that of absolute freedom, the system will have its position defined by $6\mu - 1$ co-ordinates. A screw-chain can then be chosen which is perfectly arbitrary in every respect, save that one of its screws is to be reciprocal to a given screw.

Reciprocal Screw-Chains.

We have hitherto been engrossed with the discussion of the purely kinematical relations of a mechanical system of μ elements: we now proceed to the dynamical considerations which arise when the action of forces is directed on such a system.

Each element of the system may be acted upon by one or more external forces, in addition to the internal forces which arise from the reaction of constraints. This group of forces must constitute a wrench appropriated to the particular element. For each element we thus have a certain wrench, and the entire action of the forces on the system is to be represented by a series of μ wrenches. Recalling our definition of a screw-chain, it will be easy to assign a meaning to the expression, *wrench on a screw-chain.* By this we denote a series of wrenches on the screws of the chain, and the ratio of two consecutive intensities is given by the intermediate screw, as before. We thus have the general statement:—

The action of any system of forces on a material system may be represented by a wrench on a screw-chain.

Two or more wrenches on screw-chains will compound into one wrench on a screw-chain, and the laws of the composition are exactly the same as for the composition of twists, already discussed.

Take, for example, any four wrenches on four screw-chains. Each set of four homologous screws will determine a 4-system; the resulting wrench-chain will consist of a series of wrenches on these 4-systems, each being the "parallel projection" of the other.

Let α and β be two screw-chains, each consisting of μ screws, appropriated one by one to the μ elements of the system. If a wrench act on the screw-chain α, and the system receive a twist about the screw-chain β, some work will usually be lost or gained; if, however, no work be lost or

gained, then the same will be true of a twist around α acting on a wrench on β. In this case the screw-chains are said to be reciprocal. The relation may be expressed somewhat differently, as follows:—

If a system, only free to twist about the screw-chain α, be in equilibrium, notwithstanding the presence of a wrench on the screw-chain β, then, conversely, a system only free to twist about the screw-chain β will be in equilibrium, notwithstanding the presence of a wrench on the chain α.

This remarkable property of two screw-chains is very readily proved from the property of two reciprocal screws, of which property, indeed, it is only an extension.

Let $\alpha_1 \ldots \alpha_\mu$ be the screws of one chain, and $\beta_1 \ldots \beta_\mu$ those of the other. Let α_1', α_2', $\ldots$ α_μ' denote amplitudes of twists on α_1, α_2, &c., and let α_1'', α_2'', &c., denote the intensities of wrenches on α_1, α_2, &c. Then, from the nature of the screw-chain, we must have

$$\alpha_1' : \alpha_1'' = \alpha_2' : \alpha_2'' = \alpha_3' : \alpha_3'', \text{ \&c.;}$$

for as twists and wrenches are compounded by the same rules, the intermediate screws of the chain require that the ratio of two consecutive amplitudes of the twists about the chain shall coincide with the ratio of the intensities of the two corresponding wrenches. Similar relations of course hold for β. Denoting (*Screws*, p. 13) the virtual coefficient of α_1 and β_1 by the symbol $\varpi_{\alpha_1\beta_1}$, we have for the work done by a twist about α, against the screw chain β,

$$2\alpha_1' \beta_1'' \varpi_{\alpha_1\beta_1} + 2\alpha_2' \beta_2'' \varpi_{\alpha_2\beta_2} + \text{\&c.},$$

while in the second case we have the expression

$$2\alpha_1'' \beta_1' \varpi_{\alpha_1\beta_1} + 2\alpha_2'' \beta_1' \varpi_{\alpha_2\beta_2}, \text{ \&c.};$$

but if the first of these expressions vanishes, then the second will vanish also.

It will now be obvious that a great part of the Theory of Screws may be applied to the more general conceptions of screw-chains. If a chain be reciprocal to two or more screw-chains, it will be reciprocal to every chain obtained by compounding twists on these two or more chains.

A screw-chain is defined by $6\mu - 1$ data. It follows that a finite number of screw-chains can be determined, which shall be reciprocal to $6\mu - 1$ given screw-chains. It is, however, easy to see that *that number must be one.* If two chains could be found to fulfil this condition, then every chain formed from the system by composition of two twists thereon would fulfil the same condition. We hence have the important result—

One screw-chain can always be determined which is reciprocal to $6\mu - 1$ *given screw-chains.*

This is of course only the generalization of the statement with respect to a single rigid body, that one screw can always be found which is reciprocal to five given screws.

Given $6\mu + 1$ screw-chains, it is always possible to determine the amplitudes of certain twists about those chains, such that if those twists be applied to a system in succession, the system shall, after the last twist, occupy the same position which it had before the first. In the first place it is necessary to show that from the system formed by composition of twists about two screw-chains, one chain can always be found which is reciprocal to any given chain. This is indeed the generalization of the statement that one screw can always be found on a cylindroid which is reciprocal to a given screw. The proof of the more general theorem is equally easy. The number of chains produced by composition of twists about the screw-chains α and β is singly infinite. There can, therefore, be a finite number of chains of this system reciprocal to a given chain θ. But that number must be one; for if even two chains of the system were reciprocal to θ, then every chain of the system must also be reciprocal to θ. The solution of the original problem is then as follows :—Let α and β be two of the given $6\mu + 1$ chains, and let θ be the one chain which is reciprocal to the remaining $6\mu - 1$ chains. Since the $6\mu + 1$ twists are to neutralize, the total quantity of work done against any wrench-chain must be zero. Take, then, any wrench-chain on θ. Since this is reciprocal to $6\mu - 1$ of the chains, the twists about these chains can do no work against a twist on θ. It follows that the amplitudes of the twists about α and β must be such that the total amount of work done must be zero. For this to be the case, the two twists on α and β must compound into one twist on the chain ν, which belongs to

the system $(\alpha\beta)$, and is also reciprocal to θ. This defines the ratio of the amplitudes of the two twists on α and β. We may in fact draw any cylindroid containing three homologous screws of α, β, and γ, then the ratio of the sines of the angles into which γ divides the angle between α and β is the ratio of the amplitudes of the twists on α and β. In a similar manner the ratio of the amplitudes of any other pair of chain-twists can be found, and thus the whole problem has been solved.

We are now able to decompose any given twist or wrench on a screw-chain into 6 μ components on any arbitrary 6 μ chains. The amplitudes or the intensities of these 6 μ components may be termed the 6 μ co-ordinates of the given twist or wrench. If the amplitude or the intensity be regarded as unity, then the 6 μ quantities may be taken to represent the co-ordinates of the screw-chain. In this case the ratios alone of the co-ordinates are of consequence.

If the system have only n degrees of freedom where n is less than 6 μ, then all the screw-chains about which the system can be twisted are so connected together, that if any $n+1$ of these chains be taken arbitrarily, the system can receive twists about these $n+1$ chains of such a kind, that after the last twist the system has the same position which it had before the first. In this case n co-ordinates will be sufficient to express the twist or wrench which the system can receive, and n co-ordinates, whereof only the ratios are concerned, will be sufficient to define any screw-chain about which the system can be twisted.

$6\mu - n$ screw-chains are taken, each of which is reciprocal to n screw-chains about which a system with freedom of the n^{th} order can twist. The two groups of n chains on the one hand, and $6\mu - n$ on the other, may each be made the basis of a system of chains about which a mechanism could twist with freedom of the n^{th} order, or of the $(6\mu - n)^{th}$ order, respectively. These two systems are so related that each chain in the one system is reciprocal to all the chains in the other. They may thus be called two *reciprocal systems of screw-chains.*

Whatever be the constraints by which the freedom is hampered, the reaction of the constraints upon the elements must constitute a wrench on a screw-chain. It is a fundamental point of the present theory that this screw-

chain belongs to the reciprocal system. For, as no work is done against the constraints by any displacement which is compatible with the freedom of the system, it must follow, from the definition, that the wrench-chain which represents the reactions must be reciprocal to all possible displacement chains, and must therefore belong to the reciprocal system.

For a wrench-chain applied to the system to be in equilibrium it must, if not counteracted by some other external wrench-chain, be counteracted by the reaction of the constraints. Hence we see, that of two reciprocal screw-chain systems, each expresses the locus of a wrench-chain which will equilibrate when applied to a system only free to twist about all the chains of the other system. This is, perhaps, one of the most general theorems on Equilibrium which could be enunciated.

The Principal Chains of Inertia.

Up to the present we have been only occupied with considerations involving kinematics and statics: we now proceed, in conclusion, to show how the principles of kinetics can be illustrated by the theory sketched in this Paper.

We shall suppose, as before, that the mechanical arrangement consists of μ elements, and that those elements are so connected together that the system has n degrees of freedom. We shall also suppose that the system is acted upon by a wrench about any chain whatever. The first step to be taken is to show that the given wrench-chain may be replaced by another more conveniently circumstanced. Take any n chains of the given system, and $6\mu - n$ chains of the reciprocal system, then the given wrench-chain can be decomposed into components on the $n + (6\mu - n)$ chains here specified. The latter, however, being all capable of destruction by the reaction of the constraints, may be omitted, while the former n wrench-chains admit of being compounded into a single wrench-chain. We hence have the following important proposition:—

Whatever be the forces which act on a mechanical system, their effect is always equivalent to that of a wrench on a screw-chain which belongs to the system of screw-chains expressing the freedom.

The advantage of this theorem is found in the fact that, while we still retain the most perfect generality, it is only necessary, either for twists or wrenches, to consider the chain system, defined by n chains, about which the mechanism can be displaced.

Let us consider the system to be at rest in a specified position, and suppose it receives the impulsive action of any set of forces, *it is required to determine the instantaneous motion which the system will acquire.* The first operation is to combine all the forces into a wrench-chain, and then to transform that wrench-chain, in the manner just explained, into an equivalent wrench-chain on one of the screws of the system. Let θ be the chain of the system so found. In consequence of this impulsive action the system will commence to move; that motion can, however, be nothing else than an instantaneous twist velocity about a screw-chain α. We thus have an impulsive chain θ corresponding to an instantaneous chain α. In the same way we shall have the impulsive chains ϕ, ψ, &c., correlated to the instantaneous chains β, γ, &c.

The first point to be noticed is, that the correspondence is unique. To the instantaneous chain α one impulsive chain θ will correspond. There could not be two chains θ and θ' which correspond to the same instantaneous screw α. For, suppose this were the case, then the twist velocity imparted by the impulsive wrench on θ could be neutralized by the impulsive wrench on θ'. We thus have the system remaining at rest in spite of the impulsive wrenches on θ and θ'. These two wrenches must therefore neutralize, and as, by hypothesis, they are on different screw-chains, this can only be accomplished by the aid of the reactions of the constraints. We therefore find that θ and θ' must compound into a wrench-chain which is neutralized by the reactions of the constraints. This is, however, impossible, for θ and θ' can only compound into a wrench on a chain of the original system, while all the reactions of the constraints form wrenches on the chains of the wholly distinct reciprocal system.

We therefore see that to each instantaneous chain α only one impulsive chain θ will correspond. It is still easier to show that to each impulsive chain θ only one instantaneous chain α will correspond. Suppose that there were two chains, α and α', either of which would correspond to an

impulsive wrench on θ. We could then give the system, first, an impulsive wrench on θ of intensity λ, and make the system twist about α, and we could simultaneously give it an impulsive wrench on the same chain θ of intensity $-\lambda$, and make the system twist about α'. The two impulses would neutralize, so that as a matter of fact the system received no impulse whatever, but the two twist velocities could not destroy, as they are on different chains. We would thus have a twist velocity produced without any expenditure of energy.

We have thus shown that in the n-system of chains expressing the freedom, each chain, regarded as an instantaneous chain, will correspond to one chain, regarded as an impulsive chain, and conversely. It is obvious also that the co-ordinates of an impulsive chain must be connected with those of the instantaneous chain by continuous functions. We therefore have a case of screw-chain homography established in the systems, so that if $\theta_1, \ldots \theta_n$ denote the co-ordinates of the impulsive chain, and if $\alpha_1, \ldots \alpha_n$ denote the co-ordinates of the corresponding instantaneous chain, we must have n equations of the type

$$\theta_1 = (11)\,\alpha_1 + (12)\,\alpha_2 + (13)\,\alpha_3 \ldots + (1\,n)\,\alpha_n,$$

$$\theta_2 = \ldots\ldots$$

$$\theta_n = (n\,1)\,\alpha_1 + (n\,2)\,\alpha_2 + \ldots\ldots\ldots + (nn)\,\alpha_n,$$

where (11), (12), &c., are n^2 coefficients depending on the distribution of the masses, and the other circumstances of the system. Except the equations had this form, or one equivalent thereto, the necessary one-to-one correspondence could not be observed.

We are now in a position to obtain a result of no little interest. Just as we have two double points in two homographic rows on a line, so we have n double chains in the two homographic chain systems. If we make, in the foregoing equations,

$$\theta_1 = \rho\alpha_1; \qquad \theta_2 = \rho\alpha_2, \text{ \&c.},$$

we obtain, by elimination of $\alpha_1, \ldots \alpha_n$, an equation of the n^{th} degree in ρ. The roots of this equation are n in number, and each root substituted in the equations will enable the co-ordinates of each of the n double chains to be

discovered. The mechanical property of these double chains is to be found in the following statement :—

If any mechanical system whatever have n degrees of freedom, then n screw-chains can always be found (*but not more than n*), *such that if the system receive an impulsive wrench on any one of these screw-chains, it will immediately commence to move by twisting about the same screw-chain.*

In the case where the system reduces to a single rigid body, free or constrained, the n chains to which we have just been conducted reduce to what we have called the *n principal screws of inertia*. In the case, still more specialized, of a rigid body only free to rotate around a point, the theorem degenerates to the well-known property of the principal axes. We may thus regard the n principal chains now found as the generalization of the familiar property of the principal axes for any system anyhow constrained.

Considerable simplification is introduced into the equations when, instead of choosing the chains of reference arbitrarily, we select the n principal chains for this purpose ; we then have the very simple results,

$$\theta_1 = (11)\,\alpha_1\,; \quad \theta_2 = (22)\,\alpha_2\,; \quad \ldots \quad \theta_n = (nn)\,\alpha_n.$$

This gives us a very easy method of finding the impulsive chain corresponding to any instantaneous chain. It is only necessary to multiply the co-ordinates of the instantaneous chain α_1, α_2 by the constant factors (11), (12), &c., in order to find the co-ordinates of the impulsive chain.

The general type of homography now indicated is indeed somewhat specialized for the case of impulsive chains and instantaneous chains. The n double screw-chains are generally quite unconnected—we might, indeed, have exhibited the relation between the two homographic systems of chains by choosing n screws quite arbitrarily as the double screws of the two systems, and then appropriating to them n factors (11), (22), (33), &c., also chosen arbitrarily. In the case of impulsive and instantaneous chains, the n double chains are connected together by the relation that *each pair of them are reciprocal*, so that the whole group of n chains form what may be called a set of co-reciprocals.

To establish this we may employ some other methods than those previously used. Let us take a set of n-co-reciprocal chains, and let the co-

ordinates of any other two chains, θ and ϕ of the same system, be $\theta_1, \ldots \theta_n$ and $\phi_1, \ldots \phi_n$. Let $2p_1$, $2p_2$, &c., $2p_n$ be certain constant parameters appropriated to the screws of reference. $2p_1$ is, for example, the work done by a twist of unit amplitude on the first chain of reference against a wrench of unit intensity on the same chain. The work done by a twist θ_1 against a wrench ϕ_1 on this chain is $2p_1\theta_1\phi_1$. As the chains of reference are co-reciprocal, the twist on θ_1 does no work against the wrenches ϕ_2, ϕ_3, . . . &c.; hence the total work done by a twist on θ against the wrench on ϕ is

$$2p_1\theta_1\phi_1 + \ldots + 2p_n\theta_n\phi_n;$$

and hence if θ and ϕ be reciprocal,

$$p_1\theta_1\phi_1 + \ldots + p_n\theta_n\phi_n = 0.$$

The quantities $p_1, \ldots p_n$ are linear magnitudes, and they bear to screw-chains the same relation which the pitches bear to screws. If we use the word *pitch* to signify half the work done by a unit twist on a screw-chain against the unit wrench on the screw-chain, then we have for the pitch p_θ of the chain θ the expression

$$p_1\theta_1^2 + p_2\theta_2^2 + \ldots + p_n\theta_n^2.$$

The kinetic energy of the system, when animated by a twist velocity of given amount, depends on the instantaneous screw-chain about which the system is twisting. It is proportional to a certain quadratic function of the n co-ordinates of the instantaneous screw. By suitable choice of the screw-chains of reference it is possible, in an infinite number of ways, to exhibit this function as the sum of six squares. It is also well known from the theory of linear transformations that it is possible to make one selection of the chains of reference which, besides giving the energy function the required form, will also exhibit p_θ as the sum of six squares. This latter condition means that the chains of reference are co-reciprocal. It only remains to show that the n chains of reference thus ascertained must be the n principal chains to which we were previously conducted.

We may show this most conveniently by the aid of Lagrange's equations of motion in generalized co-ordinates.

Let $\theta_1, \ldots \theta_n$ represent the co-ordinates of the impulsive screw-chain, and let $\alpha_1, \ldots \alpha_n$ be the co-ordinates of the corresponding instantaneous screw-chain, reference being made to the screw-chains of reference just found.

Lagrange's equations have the form

$$\frac{d}{dt}\left(\frac{dT}{d\dot{\alpha}_1}\right) - \frac{dT}{d\alpha_1} = -P_1,$$

where T is the kinetic energy, and where $P_1\delta\alpha_1$ denotes the work done against the forces by a twist of amplitude $\delta\alpha_1$.

If θ'' denote the intensity of the impulsive wrench, then its component on the first screw of reference is $\theta''\theta_1$, and the work done is $2p_1\theta''\theta_1\delta\alpha_1$, while, since the chains are co-reciprocal, the work done by $\delta\alpha_1$ against the components of θ'' on the other chains of reference is zero, we therefore have

$$P_1 = 2p_1\theta''\theta_1.$$

We have also

$$T = M(u_1^2\dot{\alpha}_1^2 + \ldots + u_n^2\dot{\alpha}_n^2),$$

when $u_1, \ldots u_n$ are certain constants.

We have, therefore, from Lagrange's equation,

$$\frac{d}{dt}\left(Mu_1^2\dot{\alpha}_1\right) = -p_1\theta''\theta_1,$$

whence, integrating during the small time t, during which the impulsive force acts,

$$Mu_1^2\dot{\alpha}\alpha_1 = -\theta_1 p_1 \int\theta'' dt,$$

in which $\dot{\alpha}$ is the actual twist velocity about the screw-chain, so that $\dot{\alpha}_1 = \dot{\alpha}\alpha_1$, each being merely the expression for the component of that twist velocity about the screw-chain.

We hence obtain $\theta_1, \ldots \theta_n$, proportional respectively to

$$\frac{u_1^2\alpha_1}{p_1}, \ldots \frac{u_n^2\alpha_n}{p_n}.$$

If we make $\frac{u_1^2}{p_1} = (11)$, &c., we have the previous result,

$$\theta_1 = \&c., \&c.\ (11)\ \alpha_1,$$

$$\theta_n = (nn)\ \alpha_n.$$

From the results just obtained, which relate of course only to the chains of reference, we can deduce a very remarkable property connecting instantaneous chains, and impulsive chains in general. *Let α and β be two instantaneous chains, and let θ and ϕ be the two corresponding impulsive chains, then when α is reciprocal to ϕ, β will be reciprocal to θ.* This, it will be observed, is a generalization of a property of which much use is made in the *Theory of Screws*. The proof is very easy.

The co-ordinates of the instantaneous chains are

$$\alpha_1, \ldots \alpha_n,$$

$$\beta_1, \ldots \beta_n.$$

The co-ordinates of the corresponding impulsive chains are

$$\frac{u_1^2 \alpha_1}{p_1}, \ldots \frac{u_n^2 \alpha_n}{p_n},$$

and

$$\frac{u_1^2 \beta_1}{p_1}, \ldots \frac{u_n^2 \beta_n}{p_n}.$$

If the chain α be reciprocal to the impulsive chain which produces β, then we have

$$u_1^2 \alpha_1 \beta_1 + \ldots + u_n^2 \alpha_n \beta_n = 0\,;$$

but this being symmetrical in α and β is precisely the same as the condition that the impulsive chain corresponding to α shall be reciprocal to β.

In conclusion, we make one more application of the theory of screw-chains to the discussion of a kinetical problem. Let us suppose that we have any material system with n degrees of freedom in a position of stable equilibrium under the action of a conservative system of forces. If the system receive a small displacement, the forces will no longer equilibrate, but the system will be exposed to the action of a wrench on a screw-chain. We thus have two corresponding sets of screw-chains, one set being the

chains about which the system is displaced, the other set for the wrenches which are evoked in consequence of the displacements.

It can be shown by very similar reasoning to that which we have already used, that these two corresponding chain systems are homographic. We can therefore find n screw-chains about which, if the system be displaced, a wrench will be evoked on the same screw-chain, and (the forces having a potential) it can be shown that this set of n screw-chains are co-reciprocal.

If after displacement the system be released it will continue to make small oscillations. The nature of these oscillations can be completely exhibited by the screw-chains. To a chain α, regarded as an instantaneous chain, will correspond the screw θ as an impulsive chain. To the chain α, regarded as the seat of a displacing twist, will correspond a wrench ϕ which is evoked by the action of the forces. It will, of course, generally happen that the chain θ is different from the chain ϕ. It can however be shown that θ and ϕ are not in every case distinct. There are n different screw-chains, each of which regarded as α will have the two corresponding screws θ and ϕ identical. Nor is it difficult to see what the effect of such a displacement must be on the small oscillations which follow. A wrench is evoked by the displacement, and since θ and ϕ coincide, that wrench is undistinguishable from an infinitely small impulsive wrench which will make the system commence to twist about α. We are thus led to the result that—

There are n screw-chains such that if the system be displaced by a twist about one of these screw-chains, and then released, it will continue for ever to twist to and fro on the same screw-chain.

Following the language previously used, we may speak of these as *harmonic screw-chains*, and it can be shown that whatever be the small displacement of the system, and whatever be the small initial velocities with which it is started, the small oscillations are merely compounded of twist vibrations about the n harmonic screw-chains.

Having discussed the theory of screw-chains in its application to Kinematics, to Statics, to Impulsive Forces, and to Small Oscillations, and bearing in mind that that theory is only applicable to small movements of the system, the subject of this Paper is completed.

VIII.—*On some hitherto undescribed Compounds of Selenium.* By Charles A. Cameron, M.D., Professor of Chemistry, Royal College of Surgeons, Ireland, and Edmund W. Davy, M.D., Professor of Forensic Medicine, Royal College of Surgeons, Ireland.

[Read, June 27th, 1881.]

The elementary substances Sulphur and Selenium present, as is well known, many points of resemblance as regards their physical and chemical properties; but whilst the chemistry of Sulphur has been extensively investigated, and the large number of its combinations already known, almost yearly receives some additions—little attention has been paid to Selenium, and comparatively few of its compounds have hitherto been described. The neglect which the latter substance has experienced may, in a great measure, be due to the rarity of this element, and its consequently very high price, which no doubt has deterred many from undertaking the investigation of its combinations.

Several compounds of Selenium, analogues of those of Sulphur, have already been described; and though it cannot be affirmed that corresponding combinations can in every case be formed, it is evident that a much larger number than those already known might be produced. As there exists, therefore, in this direction a considerable field for further investigation, we applied to the Royal Irish Academy for a small sum out of its Parliamentary Grant (given for the promotion of scientific research), to enable us to carry out our inquiries respecting such compounds. Our request having been complied with, we have now the honour

of submitting to the Academy a Report upon the results of our investigations in the direction indicated.

The inquiries which we have instituted have been chiefly confined to the selenates, and selenocyanides, or compounds respectively of selenic acid, and of the radical selenocyanogen, with different bases; and we have succeeded in forming several hitherto undescribed salts of each of those compounds. We shall commence with some of those of the former.

Though the compounds of sulphuric acid with mercury have been long well known, we have not been able to find in any of the chemical works or journals which we have consulted any reference to the existence of combinations of its anologue, selenic acid with that metal, so that the selenates of mercury appear to be up to the present undescribed salts. We have, however, ascertained that selenic acid is capable of forming mercuric and mercurous salts, which are perfectly analogous to the corresponding sulphates; the preparation and properties of which, commencing with the former, we shall now proceed to describe.

Neutral Mercuric Selenate, $HgSeO_4$.

Preparation.—Neutral mercuric selenate may be readily prepared by any one of the three following methods, viz:—

1st. By heating freshly precipitated mercuric oxide with selenic acid, having the sp. gr. of 1·4 or upwards, until it is changed into a white substance; the excess of selenic acid being afterwards got rid of by pouring off as much as possible of the liquid, and by subsequent evaporation and heating, bringing the residue to dryness.

2nd. By adding an excess of selenic acid to mercuric acetate, evaporating and heating the mixture to expel free selenic and acetic acids.

3rd. By digesting in selenic acid the basic mercuric selenate (a salt to be presently described) in the proportions of two molecules of the acid to one of the basic salt; the neutral mercuric selenate is readily obtained.

Properties.—Neutral mercuric selenate is a white, or yellowish-white salt, which, when deposited slowly out of its solution in acid, forms small sparkling crystals. It readily dissolves in selenic, hydrochloric, and

sulphuric acids; but is less soluble in nitric acid. If boiled with hydrochloric acid it is, like other selenates, reduced to a selenite; but no reduction takes place if the solution be cold. This neutral mercuric selenate is decomposed by water in the same way as the neutral mercuric sulphate, a basic selenate being formed, and selenic acid set free, as is shown by the following equation, $3HgSeO_4 + 2H_2O = HgSeO_4 (HgO)_2 + 2H_2SeO_4$. The selenic acid set free retains a small portion of the selenate in solution; but no acid selenate appears to exist, for we have made several attempts to form such a salt, but without success. The crystals which separate from the most acid solution of mercuric selenate are still those of the neutral salt, and when separated from free acid they are as permanent in the air as the amorphous form of the salt obtained by digesting mercuric oxide in selenic acid. In this respect mercuric selenate agrees perfectly with mercuric sulphate, which, on being treated with water, as one of us has already proved,* does not yield an acid and basic salt, as has been stated in different chemical works, but only a basic salt and free sulphuric acid, as is shown in the following equation: $3HgSO_4 + 2H_2O = HgSO_4 (HgO)_2 + 2H_2SO_4$.

Analysis.—The analysis of the neutral mercuric selenate was made as follows:—The salt, having been perfectly freed from an excess of acid, was dissolved in the smallest quantity of hydrochloric acid sufficient for the purpose; the solution was diluted with water, and saturated with chlorine; barium chloride was then added, which precipitated the selenium as barium selenate.

The filtrate was boiled in order to expel free chlorine, and hydrogen sulphide having been transmitted through it, the mercury was thrown down as a sulphide. The amount taken of perfectly dry and neutral mercuric selenate was 0·777 gram; this yielded a precipitate of barium selenate weighing 0·644 gram, equivalent to 23·42 per cent. of selenium in the mercuric selenate analysed. From the filtrate 0·524 gram of mercuric sulphide was obtained, equal to a percentage of 58·17 of mercury in the selenate. The following Table shows the results of the

* See "On the Action of Water upon Mercuric Sulphate," by Charles A. Cameron, M.D., *Scientific Proceedings* of the Royal Dublin Society, vol. ii. (new series), p. 598.

analysis of the salt as above described, and the theoretical composition of mercuric selenate in 100 parts:—

Composition of Neutral Mercuric Selenate.

	FOUND.	THEORETICAL.
Mercury, . . .	58·17	58·31
Selenium, . . .	23·42	23·06
*Oxygen, . . .	18·41	18·63
	100·00	100·00

The results of the analysis of the salt agree, therefore, very closely with the theoretical composition of a neutral mercuric selenate.

Basic Mercuric Selenate $HgSeO_4\,(HgO)_2$.

Preparation.—Basic mercuric selenate may be prepared, as already stated, by the action of water upon the neutral salt, or more readily by mixing together solutions of mercuric acetate and potassium selenate, when the following reaction takes place:—

$$3\,[Hg(C_2H_3O_2)_2]+K_2SeO_4+2H_2O=HgSeO_4(HgO)_2+2KC_2H_3O_2+4HC_2H_3O_2.$$

Properties.—Basic mercuric selenate is an amorphous substance, which when freshly precipitated is of a rich red colour, but on being dried becomes reddish-brown. It is readily soluble in hydrochloric, sulphuric, and selenic acids; but in nitric acid it less easily dissolves. When boiled with hydrochloric acid it is reduced to mercuric selenite with the evolution of chlorine. It is but very slightly soluble in water, as is shown by the following experiment:—some of the freshly precipitated basic selenate was shaken up with distilled water occasionally during three days; a liter of

* In the analysis the amount of oxygen was determined by difference.

the perfectly clear solution was then taken, and evaporated to dryness in a platinum dish, when the residue left was found to be 0·0968 gram, which was equivalent to one part of the selenate in 10,330 parts of water. Basic mercuric selenate is, therefore, more soluble than its sulphur analogue; for it has been recently proved by one of us that basic mercuric sulphate (turbith mineral) requires about 32,258* parts of water to dissolve it, instead of 3000, as stated in different chemical works.

Analysis.—The selenium in the basic mercuric selenate was estimated in the form of barium selenate in the manner already described; and it was also determined by the following method:—

The salt was strongly heated with an excess of potassium cyanide, by which the mercury was volatilized, and a potassium selenocyanide (KCySe) formed. This salt was dissolved in water, and the solution heated with hydrochloric acid, which caused a precipitation of the selenium. For the determination of the selenium by the first-mentioned of those processes, 1·262 grams of basic selenate were taken; this yielded 0·432 gram of barium selenate, containing 0·122 gram of selenium, equal to 9·67 parts of selenium in 100 of the salt. In the second process 0·636 gram was taken for ignition with potassium cyanide; this gave of precipitated selenium 0·612 gram, equal to a percentage of 9·63 in the basic mercuric selenate. The mercury was estimated by passing hydrogen sulphide gas through a solution of the selenate in hydrochloric acid, so as to produce mercuric sulphide. In this process, it is necessary to observe, that some of the selenium was converted into selenium sulphide, and some into mercuric selenide. The former was dissolved out by ammonium sulphide. The precipitated mercuric sulphide was then ignited with a mixture of disodium carbonate and potassium nitrate, the whole digested in hydrochloric acid, and hydrogen sodium sulphite added, when the mixture on being boiled deposited the selenium, the amount of which was then ascertained, and its equivalent in mercuric selenide calculated. 1·072 grams of basic mercuric selenate, gave a precipitate with hydrogen sulphide which, after washing with ammonium sulphide, weighed 0·976 gram.

* See *Scientific Proceedings* of the Royal Dublin Society, vol ii. (new series), p. 599.

This residue contained 0·0194 gram of selenium, combined with 0·0491 gram of mercury, to form 0·0685 of mercuric selenide. Deducting the latter from the residue, there remained 0·9075 gram of mercuric sulphide containing 0·7823 of mercury, which, added to 0·0491 gram, gave a total of 0·8314 gram, corresponding to a percentage of 77·55 of mercury in the selenate. A second portion of the selenate, weighing 1·089, grams gave a precipitate with hydrogen sulphide, which, after washing with ammonium sulphide, weighed 1·016 grams, and contained 0·0557 gram of selenium, combined with 0·141 gram of mercury, to form 0·1967 gram of mercuric selenide. Deducting the latter from the residue, there remained 0·8193 gram of mercuric sulphide, containing 0·7063 gram of mercury, which, added to 0·141 gram, gave a total of 0·8473 gram, corresponding to a percentage of 77·79 of mercury in the selenate.

The following are the results of those analyses.

Percentage composition of Basic Mercuric Selenate.

	Found.			Theoretical.
	First Analysis.	Second Analysis.	Mean.	
Mercury, . . .	77·55	77·79	77·67	77·43
Selenium, . . .	9·63	9·67	9·65	10·20
Oxygen, . . .	12·82	12·54	12·58	12·37
	100·00	100·00	100·00	100·00

Mercurous Selenate, Hg_2SeO_4.

Preparation.—When solutions of mercurous nitrate and potassium selenate are mixed, mercurous selenate precipitates, thus :—

$$Hg_2(NO_3)_2 + K_2SeO_4 = Hg_2SeO_4 + 2KNO_3.$$

It may likewise be obtained by substituting in this process selenic acid for the alkaline selenate.

Properties.—Mercurous selenate is a greyish-white amorphous substance. Hydrochloric acid converts it into mercuric chloride, selenious acid, and selenium; boiled with nitric acid it is converted into mercuric selenate, with the evolution of nitrogen dioxide. This salt is remarkably susceptible to the influence of light, a few moments' exposure being sufficient to cause darkening, even in diffused daylight. Like the mercuric salt, it is very sparingly soluble in water, as was shown by the following experiment: some of the freshly precipitated salt was digested for several days in distilled water, which, at the close of the experiment, had a temperature of 12·0° Cent. A liter of this solution, which was perfectly clear, left on evaporation a residuum of 0·0546 gram, equivalent to one part of the salt in 10,328 parts of water. This agrees very closely with the degree of solubility of the basic mercuric salt in water.

Analysis.—The salt was dissolved in boiling nitric acid, and the solution evaporated to dryness; this residuum was then dissolved in a little hydrochloric acid, water was added, and chlorine passed through the solution (in order to reoxidize any selenium which might have been reduced from selenic to selenious acid by the action of the hydrochloric acid): the selenium was then precipitated as barium selenate; the filtrate was evaporated to dryness with an excess of strong hydrochloric acid, and the free chlorine, and hydrochloric and nitric acids were expelled. The residue was then dissolved, and the mercury in it precipitated as sulphide.

For the estimation of the selenium, 1·333 grams of the selenate were taken; this quantity gave a precipitate of barium selenate, which amounted to 0·711 gram, containing 0·201 gram of selenium, equal to 15·08 parts in 100 parts of mercurous selenate.

For the determination of the mercury a second portion was taken, weighing 1·275 grams; from which a precipitate of mercuric sulphide weighing 1·1 grams were obtained, the mercury in it amounting to 0·948 gram, equivalent to a percentage of 74·36 in the mercurous selenate. The following

Table exhibits the results of the analysis of the salt above described, and the theoretical composition of mercurous selenate:—

Percentage composition of Mercurous Selenate.

	FOUND.	THEORETICAL.
Mercury, ...	74·36	73·67
Selenium, ...	15·08	14·56
Oxygen (by difference),	10·56	11·77
	100·00	100·00

The results of analysis, though they do not agree exactly with the theoretical formula of the selenate, are sufficiently close to prove that the salt examined was really a mercurous selenate; and all the reactions with the compound were those of a mercurous salt.

Dimercurammonium Selenate $(NHg_2)_2SeO_4 2H_2O$.

PREPARATION.—Mercuric selenate forms with ammonia a compound analogous to the so-called ammoniacal turpethum, the dimercurammonium sulphate $(NHg_2)_2SO_4 2H_2O$. Thus, when the neutral or freshly prepared, and still moist, basic selenate is treated with a strong solution of ammonia it dissolves, but on the addition of water an abundant white precipitate appears, which is the compound in question.

PROPERTIES.—When dry it is of a dull white colour, but it is blackened by exposure to the light.

This compound, on being strongly heated, is decomposed, with the evolution of nitrogen, ammonia, and the vapour of water, whilst basic mercuric selenate remains. It dissolves readily in hydrochloric acid, and in a strong solution of ammonia.

ANALYSIS.—Some of the compound obtained in the manner stated, having been carefully washed and dried, 0·695 gram of it was taken and dissolved in hydrochloric acid, the solution treated with chlorine, and the selenium precipitated as barium selenate, of which salt 0·1944 gram was obtained; this corresponds to 0·0549 gram of selenium, equal to a percentage of 7·9 in the white compound—which agrees closely with 7·85, the theoretical percentage of selenium in the salt having the formula given. From this circumstance, together with the manner in which it is obtained, there can be no doubt as to the nature of the compound, and that the formula $(NHg_2)_2SeO_4$, $2H_2O$ represents its constitution. Before leaving this compound, we may observe that we obtained a double selenate of potassium and of mercury, analogous to the double sulphate of potassium and of mercury, but this compound was not submitted to quantitative analysis.

Action of Selenic Acid upon Mercury.

We have studied the action of selenic, as compared with that of sulphuric acid on mercury. When the latter acid is heated with that metal sulphur dioxide is evolved, and variable proportions of mercuric and mercurous sulphates are formed, depending upon the relative quantities of acid and metal used, and the temperature to which they are subjected. The action of selenic acid upon mercury produces, however, both selenates and selenites; the reaction perhaps consisting in the replacement in the acid of a molecule of water by one or two atoms of metal, thus:

$$Hg + H_2SeO_4 = HgSeO_3 + H_2O;$$

or,

$$Hg_2 + H_2SeO_4 = Hg_2SeO_3 + H_2O,$$

whereby mercuric and mercurous selenites are formed. When, however, an excess of selenic acid is used, the selenite first produced is in part decomposed, and a mixture of selenite and selenate is the result. The following experiment may be adduced in proof of the foregoing statement:—Selenic acid was heated with an excess of mercury, and the resulting product, having been well drained and carefully washed, was

examined, when it was found to consist solely of mercurous selenite, and mercurous selenate. If the mercury was affected in exactly the same way by selenic acid, as it is stated the metal is by sulphuric acid, then:

$$Hg_2 + 2H_2SeO_4 = Hg_2SeO_4 + SeO_2 + 2H_2O\,;$$

when it might be said, that the mercurous selenite which we found was produced by the action of liberated selenious acid upon the mercury. In such a case, however, there would be an abundance of reduced selenium present, which we did not notice.

Selenite of Mercury.

Before we leave the selenites of mercury we may observe that it is stated in Watts's *Dictionary of Chemistry*, vol. v. p. 228, that an acid mercuric selenite may be formed by adding mercuric oxide to aqueous selenious acid, till the neutral salt formed begins to separate, then filtering and evaporating the solution, when the acid salt crystallizes in large prisms longitudinally striated, having the taste of corrosive sublimate, and containing a large quantity of water. The following experiments go to prove that no such salt exists:—

1st. Mercuric oxide was gradually added to a strong solution of selenious acid whilst kept boiling, until it became saturated; on cooling, a small quantity of very minute crystals separated. These were carefully drained, washed, and dried, and on being subjected to examination were found to be a neutral selenite, 100 parts of which contained the following:—

Composition of Mercuric Selenite.

	Found.	Theoretical.
Mercury, . . .	—	61·16
Selenium, . . .	23·68	24·16
Oxygen, ...	—	14·68
	100·00	100·00

2nd. The neutral salt is slightly soluble in boiling selenious acid, the degree of solubility increasing with the strength of the acid; but even the most concentrated solution will only take up a small fraction of the theoretical quantity required to produce the acid selenite. The addition of water to the acid solution of mercuric selenite precipitates all save a mere trace of the latter.

3rd. When the acid solution is evaporated to dryness, and the residue treated with water, the selenious acid dissolves out, leaving the neutral selenite undissolved.

4th. When a solution of mercuric acetate is added to a large excess of selenious acid, neutral selenite precipitates, and the filtrate contains the merest trace of mercury.

Neutral mercuric selenite is insoluble in water. It dissolves in warm dilute hydrochloric acid, and also in the strong acid, but in the latter with the immediate separation of selenium. It sublimes unchanged, and behaves to selenious acid in the same way that mercuric selenate does to selenic acid, and as mercuric sulphate does to sulphuric acid; those salts being soluble in their respective acids, but to a very slight extent, and separating from them on the addition of water.

It is clear from the foregoing observations that the supposed acid salt referred to in Watts's *Dictionary* was little more than selenious acid.

Selenocyanides.

The many analogies existing between selenium and sulphur, leaving but little doubt as to the capability of selenium forming a class of compounds corresponding to the sulphocyanides (which was rendered still more probable from the observations of Berzelius), led Mr. W. Crookes to undertake the investigation of this subject, the result of which was his discovery of a number of selenocyanides, a description of which he published in the year 1852, in the 4th vol. of the *Journal of the Chemical Society of London*. Although it is now just thirty years since Mr. Crookes discovered those salts, yet very little has been added to our knowledge of the selenocyanides; we therefore directed our attention to the subject,

and have succeeded in forming several simple and double selenocyanides which have not, we believe, been hitherto obtained. Amongst the first, we especially wish to direct attention to the mercuric and mercurous selenocyanides, as Mr. Crookes states that all his attempts to produce a simple selenocyanide of mercury failed. This circumstance may be accounted for by his having endeavoured to form that salt by the action of mercuric chloride on potassium selenocyanide, using the former salt in excess; when he obtained, as he has shown, a double salt of mercuric selenocyanide and mercuric chloride. We have found, however, that if mercuric acetate or nitrate be employed instead of mercuric chloride in acting on a soluble selenocyanide, mercuric selenocyanide readily precipitates.

Mercuric Selenocyanide, $Hg(CySe)_2$.

Preparation.—We prepared this salt by precipitating mercuric acetate with potassium selenocyanide: the precipitate was collected, and dried by pressure between folds of bibulous paper, and afterwards by being placed in the usual way over sulphuric acid, as the heat of the water-bath is sufficient to decompose it.

Properties.—Mercuric selenocyanide is a greyish-white compound, which is very sparingly soluble in cold water, but by boiling it dissolves to a greater extent. It is soluble in warm dilute hydrochloric acid, with separation of selenium, according to the equation $Hg(CySe)_2 + 2HCl = HgCl_2 + 2HCy + Se_2$. It dissolves freely in alkaline cyanides, selenocyanides, and sulphocyanides, with all of which it forms double salts. In a hot solution of mercuric chloride it is likewise soluble, and the solution on cooling yields beautiful feathery crystals of the mercuric selenocyanide and chloride, the double salt already described by Mr. Crookes. Mercuric selenocyanide darkens on exposure to light, and becomes of a greyish-brown colour, and when strongly heated it decomposes in a remarkable way, similar to that of its sulphur analogue, the combustion of which produces the intumescence known as Pharaoh's Serpents. This decomposition in the case of the mercuric selenocyanide, is attended with the separation of selenium.

Analysis.—The analysis of this salt was made by heating a given quantity with dilute hydrochloric acid, drying and weighing the separated selenium. Through the filtrate, after separation of the selenium, hydrogen sulphide was passsed, and the mercury estimated as sulphide.

For the estimation of the selenium 1·6545 grams were taken, containing 0·106 per cent. of water (as it was not thoroughly dried). This quantity gave 0·643 gram of selenium, equal to a percentage of 38·92 when corrected for moisture.

For the determination of the mercury a second portion was taken, weighing 1·268 grams; this gave 0·7115 gram of mercuric sulphide, containing 0·6134 gram of mercury, equal to a percentage of 48·43 of mercury. The following are the results of the analysis:—

Composition of Mercuric Selenocyanide.

	Found.	Theoretical.
Mercury, . . .	48·43	48·76
Selenium, . . .	38·92	38·56
Cyanogen, . . .	12·65	12·68
	100·00	100·00

Mercurous Selenocyanide, $Hg_2(CySe)_2$.

Preparation.—Mercurous selenocyanide is prepared by adding a solution of an alkaline selenocyanide to one of mercurous nitrate. The precipitate thrown down must be partially dried by pressure between folds of bibulous paper, or upon porous slabs, and then completely desiccated over sulphuric acid, for the heat of the water-bath decomposes it, as in the case of the mercuric salt.

Properties.—Mercurous selenocyanide is an olive-green amorphous compound, which is very insoluble in water. Nitric acid converts it into

mercurous selenate, and hydrochloric into mercurous chloride, with separation of selenium. It is soluble in aqua regia, which changes it into mercuric chloride and selenate. When heated to a high temperature it intumesces, but not to nearly the same extent as does the mercuric selenocyanide.

Analysis.—The analysis was made by dissolving the selenocyanide in aqua regia, diluting the solution with water, and saturating it with chlorine, after which the selenium was precipitated as barium selenate. The filtrate, after the addition of hydrochloric acid, was evaporated to dryness, to expel the chlorine and nitric acid; and the residue having been dissolved in water, and saturated with hydrogen sulphide, the mercury present was thus converted into sulphide, and estimated as such.

For the estimation of the selenium 0·972 gram of the selenocyanide was taken, which yielded 0·9072 gram of barium selenate, equivalent to a percentage of 22·36 of selenium in the mercurous selenocyanide.

In the determination of the mercury 3·48 grams furnished 2·471 grams of mercuric sulphide, equal to a percentage of 65·72 of mercury in the selenocyanide. The following Table shows the results of those analyses compared with the theoretical composition of the salt:—

Composition of Mercurous Selenocyanide.

	Found.	Theoretical.
Mercury, . . .	65·56	65·72
Selenium, . . .	25·90	26·36
Cyanogen, . . .	8·54	7·92
	100·00	100·00

Ammonium Selenocyanide, NH_4CySe.

This salt, though previously described oy Mr. Crookes, is here noticed, as we have prepared it by a new process, which consisted in digesting in

alcohol a mixture of potassium selenocyanide and ammonium sulphate; and which was found to be a very ready means of preparing this compound.

Ammonium selenocyanide very closely resembles its sulphur analogue, but decomposes very readily. Its solution in water is attended by the production of a great degree of cold.

Our attempts to form selenurea by heating ammonium selenocyanide have given as yet unsatisfactory results, though we have reason to suppose that some selenurea was thus formed.

Double Selenocyanides.

Our investigations have shown the capability of the formation of a number of double selenocyanides (some of which are readily crystallizable, and are more or less permament salts), analogous to the corresponding double sulphocyanides; some of the more interesting of these salts we shall now briefly describe.

Potassium Selenocyanide and Mercuric Cyanide, $KCySe + HgCy_2$.

Preparation.—When to an aqueous, or better still, alcoholic solution of potassium selenocyanide, a strong solution in water of mercuric cyanide is added, an immediate crystalline precipitate is formed, which, when dry, presents a white silky appearance. A quantity of this salt was prepared, by adding to an alcoholic solution of potassium selenocyanide a cold saturated aqueous one of mercuric cyanide, till the latter salt produced no further precipitate, and was in slight excess. The precipitate so formed was then thrown on a filter, and washed with a little alcohol; and having been left to drain, was afterwards dried by being placed on bibulous paper, and by subsequent exposure to the air for some days.

Analysis.—A given weight (0·3 gram) of the salt prepared as just described being taken, it was heated in a water-bath for some hours, and re-weighed, when it was found to have undergone no loss in weight, showing that it contained no water of crystallization. The salt was then dissolved in distilled water, hydrochloric acid added, and the mix-

ture gently heated, when its selenium slowly separated, hydrocyanic acid being at the same time evolved. After this separation was complete, the selenium was collected on a weighed filter, and being well washed and dried, its quantity was determined. The filtrate was then treated with an aqueous solution of hydrogen sulphide, and the mercury precipitated as a sulphide, and estimated. The filtrate from the mercuric sulphide was then evaporated to dryness in a weighed platinum capsule, and heated to incipient redness, and from the weight of the residuary potassium chloride, the amount of potassium itself determined. The results so obtained gave the following percentages of selenium, mercury, and of potassium, which it will be seen agree very closely with the theoretical percentages of those substances in a salt having the formula KCySe + $HgCy_2$, or where one molecule of potassium selenocyanide unites with one of mercuric cyanide, as is shown in the following Table:—

Potassium Selenocyanide and Mercuric Cyanide.

	Found.	Theoretical.
Selenium, . . .	19·96	19·94
Mercury, . . .	50·30	50·47
Potassium, . .	10·64	9·87

From the close agreement between the quantities found and the theoretical amounts, there can be no doubt that the formula given represents the true nature of this salt.

Properties.—This compound when dry, as already observed, presents a white silky appearance, and examined under the microscope is found to consist of long and fine prismatic crystals, which appear to undergo no change by exposure to the air, even after a very considerable period. It dissolves but slowly and sparingly in cold water, and is still more difficult of solution in cold alcohol, but is much more soluble in both liquids when heated; and on cooling either solution, if it is sufficiently saturated, long

prismatic crystals of the salt appear. It is soluble only to a very slight extent in ether, even when boiled in it, and the very minute quantity taken up, on the evaporation of that liquid, remains in prismatic crystals of the same form as when the salt crystallizes from an aqueous or alcoholic solution.

Before leaving this salt, we may observe that it can be readily obtained not only by the process already described, but likewise by simply boiling together in water for a short time potassium and mercuric cyanides, along with precipitated selenium, and filtering the mixture whilst still hot, when the filtrate on cooling yields in the crystalline form a considerable quantity of this compound. By this very simple process, therefore, we can, in the preparation of this double salt, dispense with the direct use of the potassium selenocyanide, which is a rather difficult and troublesome compound to prepare separately, at least in a state approaching purity.

Potassium Selenocyanide and Mercuric Sulphocyanide, $KCySe + Hg(CyS)_2$.

Preparation.—This salt is formed when an aqueous solution of potassium selenocyanide is heated along with mercuric sulphocyanide. The solution being filtered, to separate the black matter that is formed, which consists of mercuric selenide, the filtrate on cooling yields long prismatic colourless crystals of this double salt, which when dry possess a somewhat glistening appearance. It being ascertained that this salt could be formed, as in the case of the double salt containing mercuric cyanide (just described), by simply boiling an aqueous solution of potassium cyanide along with mercuric sulphocyanide and precipitated selenium, a larger quantity of it was so prepared, which, after recrystallization, draining, and washing with a little distilled water, was dried by means of bibulous paper, and by subsequent exposure to the air for some days.

A given weight (0·5 gram) of this salt was heated in the water-bath for some hours, and reweighed, when no loss of weight was detected, showing that it contained no water of crystallization. Its selenium, mercury, and potassium were then determined, as in the case of the double salt already described.

Properties.—This salt is rather slowly and sparingly soluble in both water and alcohol when cold, but dissolves in either more readily, and in much larger quantities, on the application of heat; and on cooling, or by evaporation of either solution, long flat prismatic crystals separate, which possess considerable permanence. Some of this salt was exposed to the air and light for several months, without its crystals apparently undergoing any change, and they retained the peculiar glistening white or silky appearance. This salt is soluble to some extent in ether—at least when boiled in that liquid—and the solution, on evaporation, yields a small quantity of its prismatic crystals. This compound, on being treated with ferric chloride, develops the intense blood-red reaction of the sulphocyanides, and when heated with hydrochloric acid, selenium separates, accompanied with the evolution of hydrocyanic acid; and lastly, when heated in a tube it yields, besides other products, a sublimate of metallic mercury. These latter properties clearly show that this salt is a double one, consisting of potassium selenocyanide and mercuric sulphocyanide.

Potassium Selenocyanide and Mercuric Iodide, $KCySe + HgI_2$.

Preparation.—Mercuric iodide dissolves readily in an aqueous or alcoholic solution of potassium selenocyanide, forming a colourless or faintly yellowish solution, which, if it is not too dilute, after a few moments yields a colourless crystalline salt. The same compound was formed in larger quantity by boiling a strong aqueous solution of potassium cyanide along with precipitated selenium and mercuric iodide, as in the case of the two new salts already described, when after filtering the hot mixture, to separate the undissolved selenium and a blackish matter that is formed, which appears to be mercuric selenide, the filtrate on cooling yields crystals of this new salt. Some of this compound which had been dried, as in the case of the former salts, by contact with bibulous paper, and by subsequent exposure to the air, when heated for some hours in a water-bath, underwent a loss in weight, and acquired a dullish appearance, which would indicate that it contained water of crystallization; and the loss of weight so experienced agreed pretty closely with that which should have re-

sulted from one molecule of water being united with one of the anhydrous salt.

Properties.—This compound possesses a pure white and somewhat pearly appearance, and when crystallized from its aqueous solution assumes the form of very thin plates, which are mostly irregular in their outline; but a small proportion of the crystals were observed to be prismatic, with right or acute angles. It is sparingly and slowly soluble in cold water and alcohol, but dissolves readily in either solvent on the application of heat, and on cooling or on evaporating the alcoholic solution, the salt crystallizes in long prismatic crystals, totally unlike the form of those from an aqueous solution, which is probably due to the former containing no water of crystallization. It is only very sparingly soluble in ether, even when boiled in it for some time, but this etherial solution, when evaporated, yields a minute residue, in which very small crystals of the same form as those in the case of the alcoholic solution are observable. In chloroform the salt is still less soluble than in ether; but the very minute quantity dissolved by boiling chloroform, on the evaporation of that liquid, furnished minute crystals of the same character as those from the alcoholic and etherial solutions. When this double salt is treated with diluted hydrochloric acid it immediately acquires a light yellow colour, which soon passes to an orange or scarlet, from the separation of the mercuric iodide, which subsequently dissolving in the excess of acid, if such be present, the solution becomes perfectly colourless, whilst hydrocyanic acid is evolved—but this solution, on being heated, gradually acquires a deep reddish-brown colour in consequence of the separation of selenium.

The determination of the selenium, mercury, and potassium of this salt, and of the preceding one, was effected as already described in the case of the double salt containing mercuric cyanide. Owing however to the peculiar nature of these latter two salts, rendering their exact determination a matter of difficulty, the results were not so satisfactory as in the case of that salt, comparing the quantities found with the theoretical amounts contained in the salts having the formulæ given; still they were sufficiently near to show that such represented their constitution.

Before leaving this salt it should be observed, that where it is prepared

by the method last described, it is necessary for the success of its preparation, that the potassium cyanide should be in considerable excess, for where only that which was required to dissolve the mercuric iodide was employed, it was unsuccessful as regards the production of the salt in question. An attempt was made to form a corresponding double salt with the green or mercurous iodide; but, on treating that iodide with a solution of potassium selenocyanide, metallic mercury separated, with the formation of the double salt just described.

Potassium Selenocyanide and Mercuric Chloride, $KCySe + HgCl_2$.

Preparation.—When to an aqueous or alcoholic solution of potassium selenocyanide, mercuric chloride in strong aqueous solution is added, drop by drop, either no apparent effect is at first produced, or if a white precipitate is occasioned, it instantly redissolves and disappears up to a certain point, when a colourless crystalline salt is formed which remains. This is a compound of potassium selenocyanide and mercuric chloride—a salt which is analogous to the double salts already described.

Properties.—When dry it possesses a pure white colour, and examined under the microscope, it is found to consist of long prismatic crystals. It is like the preceding double salts, sparingly soluble in water and alcohol at the ordinary temperature, but in both, when heated, it dissolves much more freely. It seems to be a permament salt, having undergone no apparent change by exposure to the air for a considerable time.

Analysis.—Some of the salt which had been obtained by the gradual addition (as long as any further precipitate was produced) of a saturated aqueous solution of mercuric chloride, to an alcoholic one of potassium selenocyanide, was collected on a filter, drained, and pressed between bibulous paper, to remove as much as possible of any liquid adhering to the salt; it was again dissolved in boiling alcohol, from which it separated on cooling. It was then collected, drained, and dried by the aid of bibulous paper, and by exposure to the air for about twenty-four hours; after which a certain weight (0·2 gram) was taken and heated in the water-bath for some time and reweighed, when it was found that it had undergone no loss in weight, showing that it contained no water

of crystallization. The determination of its constituent, selenium, mercury, and potassium, was then made, as in the case of the first double selenocyanide, when the following percentages were obtained:—

Potassium Selenocyanide and Mercuric Chloride.

	FOUND.	THEORETICAL.
Selenium, . . .	19·32	19·03
Mercury, . . .	49·14	48·18
Potassium, . .	9·24	9·41

These results, as to the proportions of selenium, mercury, and potassium, thus agreeing so closely with the theoretical amounts contained in a salt having the formula already given, leave no doubt that such represents its constitution.

Our observations and results as regards this salt appear to be opposed to those of Mr. Crookes, who has stated that he obtained by the action of potassium selenocyanide on mercuric chloride a yellow salt, consisting of mercuric selenocyanide and mercuric chloride. But in his experiments an excess of the mercuric chloride was employed in forming his double salt, whereas, in this case, it was carefully avoided, and under these two opposite conditions two different salts appear to have been formed.

Potassium Selenocyanide and Mercuric Bromide, $KCySe + HgBr_2$.

PREPARATION AND PROPERTIES.—Mercuric bromide acts in a perfectly similar manner to that of the mercuric chloride on potassium selenocyanide, and forms a corresponding double salt with it under the same conditions as those in the case of the chloride. It may be produced by the action of mercuric bromide directly on potassium selenocyanide; or, as in the case of the preceding double salts, by boiling together in water due proportions of potassium cyanide and precipitated selenium, and then adding the mercuric salt, and, after heating for a short time, filtering

the mixture whilst still hot, when the filtrate on cooling, yields crystals of the double salt.

This salt crystallizes in long flat prismatic crystals, which have a glistening appearance like the other double salts: it is sparingly soluble in cold water and in alcohol, though it dissolves more freely in both when heated. The salt is anhydrous, and appears to undergo no change by exposure to the air.

Though the salt was not submitted to a quantitative analysis, there can be no doubt that its constitution is analogous to that of the preceding double salts, and consists of one molecule of potassium selenocyanide united to one of mercuric bromide.

The Atomic Weight of Selenium.

Before concluding our Report, we wish to observe that the atomic weight assigned to selenium varies considerably in the different standard works on Chemistry. Berzelius, who discovered this elementary substance in 1817, calculated its atomic weight to be 494·583, the atomic weight of oxygen being 100, or 39·631 times that of the double atom of hydrogen. This, therefore, corresponds to 79·262, hydrogen having an atomic weight of one. In Gmelin's *Handbook of Chemistry* the atomic weight of selenium is set down as 80; in Watts's *Dictionary of Chemistry* it is 79·4; in Tidy's *Handbook of Modern Chemistry* it is 79·5; in Watts's edition of Fownes's *Manual of Chemistry* it is 79·4; in Miller's *Elements of Chemistry* it is 79·46; in Roscoe and Schorlemmer's *Chemistry*, at page 52, the atomic weight is given as 78, and in page 354 it is stated to be 79. Otto Pettersson and Gustav Eckman state that the results of a great many analyses show that the most probable atomic weight of selenium is 79·08 ("Berichte der Deutschen Gesellschaft," zu Berlin, No. 14, 1876). From theoretical considerations, Maximillian Gerber considers that 79·8 is the probable atomic weight of selenium. In our analyses we assumed 79 as being the atomic weight of this element.

In concluding our Report, we have to acknowledge the valuable assistance which was given to us in its preparation by Mr. John Macallan, F.I.C., Demonstrator of Chemistry in the School of the Royal College of Surgeons in Ireland.

IX.—*Certain Problems in the Dynamics of a Rigid System Moving in Elliptic Space.* By Robert S. Ball, LL.D., F.R.S., Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer of Ireland.

[Read, 14th November, 1881.]

Preliminary.—By the expression Elliptic Space I mean the more generalized conception of three-dimensioned space of which the metric properties first studied by Cayley have been further developed by Klein, Lindemann, Clifford, and others. I have followed Clifford in calling this Elliptic Space, though nothing here contained would not equally apply to hyperbolic space. The name Elliptic Space is perhaps preferable to that of Non-Euclidian Space, which has been sometimes used. It is the object of the present Memoir to take the fundamental step for re-writing the Theory of Screws in Elliptic Space.

The Vector.—This name was applied by Clifford to a particular description of displacement which a body can receive in elliptic space. In the most general displacement of a rigid system two right generators and two left generators of the absolute remain unaltered. In the movement which we call a *vector*, two of the generators of one system and all the generators of the other remain unaltered. Clifford has shown that when a body is displaced by a vector each point of the body moves through equal distances along parallel lines. He also shows that the vector could be produced by a rotation round any one of these parallel lines, accompanied by a rotation of equal amplitude around its conjugate polar. He distinguishes between a right vector and a left vector, according to which system of generators

remains unaltered, and he enunciates the fine theorem, that any displacement (which he calls a *motor*) is the sum of a right and left vector. It is from these results that the present departure is taken.

Properties of Vectors.—I shall first enunciate and prove some simple properties of vectors which will be necessary to our progress.

Two Homonymous Vectors compound into one Homonymous Vector.

A pair of (say) left vectors cannot disturb the right generators of the absolute, take two such generators, AB and $A'B'$ (Fig. 1). Let AA', BB', CC' be three left generators which the first vector conveys to $A_1A'_1$, $B_1B'_1$, $C_1C'_1$, and the second vector further conveys to $A_2A'_2$, $B_2B'_2$, $C_2C'_2$. Let X and Y be the double points of the two homographic systems defined by A, B, C and A_2, B_2, C_2. Then we have

$$(ABCX) = (A_2B_2C_2X),$$

and

$$(ABCY) = (A_2B_2C_2Y).$$

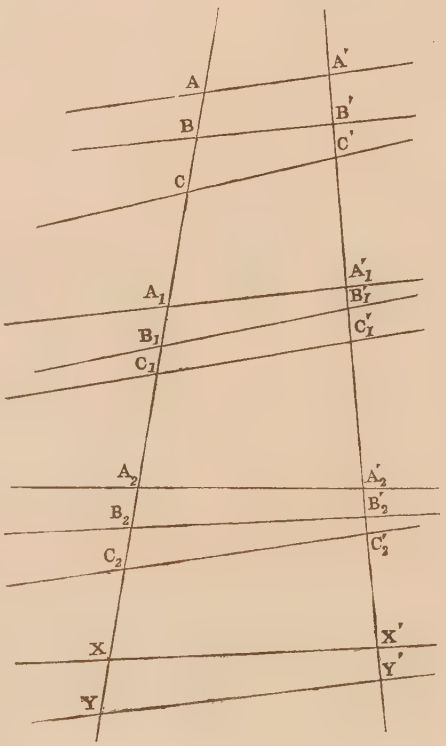


Fig. 1.

As anharmonic ratios cannot be altered by any rigid displacement, it follows that X and Y must each occupy the same position after the second vector which they had before the first, similarly, X' and Y' will remain unchanged, and as the two rays, AB and $A'B'$ are divided homographically, it follows that XX' and YY' are both generators. We therefore find that after the two vectors all the right generators remain as before, and so do also two left generators, *i. e.* the result of the two vectors could have been attained by a single vector homonymous therewith.

If two homonymous vectors are rectangular, then the two pairs of indicating generators intersect any common transversal harmonically.

Each vector displaces a point P in a certain direction, and if these directions are at right angles then the vectors are said to be rectangular (of course the definition of a right angle is, that when two intersecting lines are rectangular each of them must intersect the conjugate polar of the other).

Let DD' and DB be the directions in which any point D is displaced by the two vectors. DD' intersects two left generators in D' and P, and

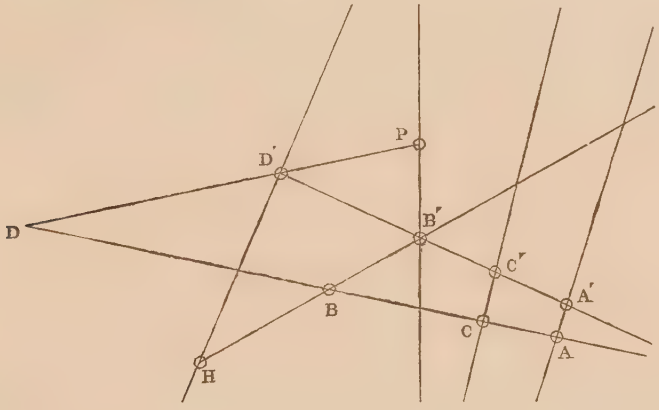


Fig. 2.

DB intersects two left generators in C and A. Let BB' be the conjugate polar of DD', then since DD' and DB are rectangular, this conjugate polar must intersect DC in B; while, from a well-known property, it must intersect the generators HD' and PB'. The line $DBCA$ is therefore cut harmonically. Draw through the ray $A'D'$ the four planes, $A'D'D$, $A'D'B$, $A'D'C$, $A'D'A$: these planes must form an harmonic pencil, and as they are tangent planes the four points of contact must also be harmonic; but these points are $B'D'C'A'$, and hence the two pairs of generators divide a transversal harmonically.

If three homonymous vectors are coplanar, then the three pairs of indicating generators intersect any common transversal in three pairs of points which are in involution.

If the vectors displace a point P along coplanar directors PA, PB, PC, and if PO be the normal to the plane, then a homonymous vector can be found which would displace P along PO; the two indicating generators of this vector must cut any generator of the other system in the two double

points of the involution. Just as we have three rectangular translations in ordinary space, so it is often convenient to use three rectangular vectors in non-Euclidian space, by means of which any other homonymous vector may be decomposed into three rectangular constituents.

It will be useful to obtain analytical methods of studying the vectors, as many of their properties can be investigated with great ease.

Let x_1, x_2, x_3, x_4 denote the four quadruplanar co-ordinates of a point. Let us suppose that this point be deranged by linear transformation to another point x'_1, x'_2, x'_3, x'_4. Then we have the following relations :—

$$x'_1 = (11)x_1 + (12)x_2 + (13)x_3 + (14)x_4,$$
$$x'_2 = (21)x_1 + (22)x_2 + (23)x_3 + (24)x_4,$$
$$x'_3 = (31)x_1 + (32)x_2 + (32)x_3 + (34)x_4,$$
$$x'_4 = (41)x_1 + (42)x_2 + (43)x_3 + (44)x_4.$$

We have first to specialize this very general transformation, so that it shall not only fulfil the necessary condition of retaining the fundamental quadric unaltered, but that it shall also be of that particular character which we have termed a vector.

The tetrahedron of reference being arbitrary, we may choose it so that two of its opposite edges shall be right generators of the absolute. We need only consider left vectors defined by a pair of left generators. In the movement denoted by any left vector all the right generators remain, of course, unaltered.

The equation of the absolute may then, with sufficient generality, be written,

$$x_1x_3 + x_2x_4 = 0.$$

Let the pair of right generators be

$$x_1 = 0, \qquad x_2 = 0,$$

and

$$x_3 = 0, \qquad x_4 = 0.$$

Then, since when $x_1 = 0$ and $x_2 = 0$, we must have $x'_1 = 0$ and $x'_2 = 0$; and

since when $x_3 = 0$ and $x_4 = 0$, we must have $x'_3 = 0$ and $x'_4 = 0$, the original equations are at once reduced to the form

$$\begin{aligned} x'_1 &= (11)x_1 + (12)x_2, \\ x'_2 &= (21)x_1 + (22)x_2, \\ x'_3 &= \qquad\qquad (33)x_3 + (34)x_4, \\ x'_4 &= \qquad\qquad (43)x_3 + (44)x_4. \end{aligned}$$

These equations are still not sufficiently specialized. They do not yet necessarily imply that *all* the right generators are to remain unaltered. The equations of a right generator are

$$\begin{aligned} x_1 - \lambda x_4 &= 0, \\ x_2 + \lambda x_3 &= 0. \end{aligned}$$

If these conditions be fulfilled by the co-ordinates of a point before the displacement produced by the vector, then they must also be fulfilled after the displacement produced by the vector, whence we must have

$$\begin{aligned} x'_1 - \lambda x'_4 &= 0, \\ x'_2 + \lambda x'_3 &= 0. \end{aligned}$$

We have by substitution the following conditions:—

$$\begin{aligned} (11) - (44) &= 0, \\ (12) + (43) &= 0, \\ (21) + (34) &= 0, \\ (33) - (22) &= 0. \end{aligned}$$

The specialization is now complete. We may conveniently change the notation as follows:—

Let

$$\begin{aligned} (11) = \quad (44) &= a, \\ (12) = -(43) &= a', \\ (22) = \quad (33) &= b, \\ (21) = -(34) &= b', \end{aligned}$$

then the equations defining the vector assume the simple type

$$\begin{aligned} x'_1 &= ax_1 + a'x_2, \\ x'_2 &= b'x_1 + bx_2 \\ x'_3 &= \qquad\quad bx_3 - b'x_4, \\ x'_4 &= \qquad\quad -a'x_3 + ax_4. \end{aligned}$$

As a verification we may transform the absolute

$$x'_1 x'_3 + x'_2 x'_4 = 0 :$$

by substitution it becomes

$$(ab - a'b')(x_1x_3 + x_2x_4) = 0.$$

Excluding the factor $(ab - a'b')$ we see that the vector is unable to remove any point from the absolute. If, however, $ab - a'b' = 0$, then the vector is such as would carry every point to infinity, without exception. The four quantities, a_1, b_1, a'_1, b'_1, may, with some convenience, be regarded as the co-ordinates of the vector. They contain, implicitly, everything relating to its amount and direction.

The double left generators appropriate to the vector can be now readily found. Any left generator is typified by

$$\begin{aligned} x_1 - \lambda x_2 &= 0, \\ x_4 + \lambda x_3 &= 0 ; \end{aligned}$$

then, since the double left generators are unaltered, we must have

$$\begin{aligned} x'_1 - \lambda x'_2 &= 0, \\ x'_4 + \lambda x'_3 &= 0 ; \end{aligned}$$

whence, by substitution, we have for the two values of λ,

$$a' + (a - b)\lambda - b'\lambda^2 = 0.$$

The length of the displacement produced by a vector can be expressed directly in terms of a, b, a', b'. It will be convenient to investigate this question in a general manner.

Let $U = 0$ denote the absolute, and let us investigate the intersection of the absolute with the line joining the points x_1, x_2, x_3, x_4, and x'_1, x'_2, x'_3, x'_4. Substituting, according to the well-known principle, the quantities $x_1 + \lambda x'_1$, $x_2 + \lambda x'_2$, $x_3 + \lambda x'_3$, $x_4 + \lambda x'_4$, the equation of the quadric becomes

$$U + 2\lambda L + \lambda^2 U' = 0,$$

where,

$$L = x'_1 \frac{dU}{dx_1} + x'_2 \frac{dU}{dx_2} + x'_3 \frac{dU}{dx_3} + x'_4 \frac{dU}{dx_4}.$$

The anharmonic ratio of the section of the line joining the two points by the quadric is

$$\frac{L - \sqrt{L^2 - UU'}}{L + \sqrt{L^2 - UU'}}.$$

The distance between the two points is therofore

$$c \log \frac{L - \sqrt{L^2 - UU'}}{L + \sqrt{L^2 - UU'}},$$

where c is the constant appropriate to the units which are chosen. We now apply this to the quadric

$$x_1 x_3 + x_2 x_4 = 0.$$

Since the vector displaces all points equally, we may, without restriction, make $x_1 = 0$ and $x_3 = 0$, so that we have

$$\begin{aligned} x_1 &= 0, & x'_1 &= + a' x_2, \\ x_2 &= x_2, & x'_2 &= + b x_2, \\ x_3 &= 0, & x'_3 &= - b' x_4, \\ x_4 &= x_4, & x'_4 &= + a x_4. \end{aligned}$$

With these substitutions the required distance becomes

$$c \log \frac{a + b - \sqrt{(a - b)^2 + 4a'b'}}{a + b + \sqrt{(a - b)^2 + 4a'b'}}.$$

We may here note the confirmation of the fact, that if the condition

$$ab - a'b' = 0$$

be fulfilled, the distance is infinite.

If the vector be small, *i. e.* if the distance through which each point be moved is small, then the quantities a' and b' are small, and a and b are nearly equal. In this case, which is of very great importance in Dynamics, the preceding expression may be reduced to the simple form

$$2c\,\frac{\sqrt{(a-b)^2 + 4a'b'}}{a+b}.$$

Condition that two Vectors should be rectangular.—The two pairs of left generators are defined by the equations

$$a'_1 + (a_1 - b_1)\lambda - b'_1\lambda^2 = 0,$$

$$a'_2 + (a_2 - b_2)\lambda - b'_2\lambda^2 = 0,$$

where the suffices 1 and 2 distinguish the two vectors. The required condition is obtained at once by expressing the condition that the invariant of the two quadratics vanishes, which is therefore

$$(a_1 - b_1)(a_2 - b_2) + 2a'_2 b'_1 + 2a'_1 b'_2 = 0.$$

Conditions that two Vectors shall be coincident in direction.—In this case it is obvious that the two pairs of double generators must coincide, the conditions for which are,

$$\frac{a'_1}{a'_2} = \frac{a_1 - b_1}{a_2 - b_2} = \frac{b'_1}{b'_2}.$$

Coplanar Vectors.—Let there be three vectors which are parallel to the same plane, and let a_0, b_0, a'_0, b'_0 be the co-ordinates of a vector which is perpendicular to this plane, then we must have the following equations satisfied:—

$$(a_1 - b_1)(a_0 - b_0) + 2a'_0 b'_1 + 2a'_1 b'_0 = 0,$$

$$(a_2 - b_2)(a_0 - b_0) + 2a'_0 b'_2 + 2a'_2 b'_0 = 0,$$

$$(a_3 - b_3)(a_0 - b_0) + 2a'_0 b'_3 + 2a'_3 b'_0 = 0,$$

whence we derive the required condition by the elimination of a_0, b_0, a_0', b_0', to be

$$\begin{vmatrix} a_1 - b_1, & a'_1, & b'_1 \\ a_2 - b_2, & a'_2, & b'_2 \\ a_3 - b_3, & a'_3, & b'_3 \end{vmatrix} = 0.$$

It is now easy to prove the theorem previously shown, that

If a system of homonymous vectors have double generators which are intersected by any opposite generator in pairs of points in involution, then each vector displaces any point in such a manner that all the displacements which each point can experience are coplanar.

The condition that the three quadratics,

$$a'_1 + (a_1 - b_1)\lambda - b'_1\lambda^2 = 0,$$

$$a'_2 + (a_2 - b_2)\lambda - b'_2\lambda^2 = 0,$$

$$a'_3 + (a_3 - b_3)\lambda - b'_3\lambda^2 = 0,$$

shall denote a set of points in involution is the evanescence of the determinant just written.

We can also see the following very useful theorems :—

If three homonymous vectors neutralize, then the three corresponding pairs of generators are in involution.

The double generators of the involution are appropriate to the vector which displaces each point along the normal to the plane in which it is displaced by any one of the coplanar vectors.

Geometrical proof.—On account of the importance of the preceding results it will be desirable to demonstrate them in a different manner by the aid of Geometry.

Through any point O draw the plane containing all the displacements of O. This plane cuts the quadric in the conic $XPYQ$, to which the two tangents OX and OY and the chord OPQ are drawn. The theorem to be proved is that the left generators through P, Q, and those through X, Y, are cut harmonically by any right generator.

The figure here drawn represents the tetrahedron formed by the tangent planes at X and Y, and the generators through X and Y. The conjugate polar of XY passes through O, and the chord OS intersects the surface at

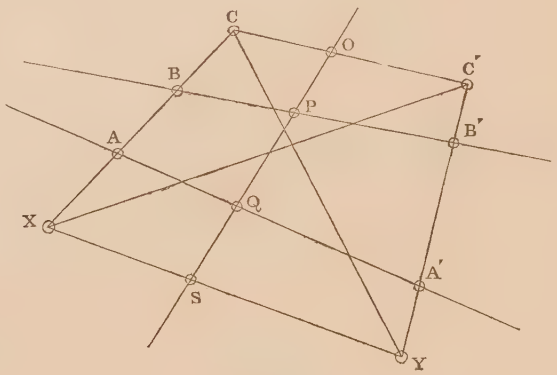


Fig. 3.

the two points P and Q, through which two left generators can be drawn. It is manifest that the four rays, CC', BB', AA', XY, have three common transversals. We must therefore have

$$(CBAX) = (OPQS).$$

But from the known property of conjugate polars the latter ratio is harmonic. The former is therefore also harmonic, *i. e.* the pair of left generators through X and Y, and those through P and Q, are cut harmonically by any right vector.

It is therefore obvious that all the pairs of left generators through P and Q (where OPQ is any chord through O) form an involution with the left generators through X and Y as the double generators of the system.

Condition that three Vectors shall neutralize.—In the case where the magnitudes of the vectors are small, the condition that they shall neutralize admits of being stated with great simplicity in terms of the co-ordinates of the vectors.

Let the three vectors be a_1, b_1, a'_1, b'_1, &c., then the necessary and sufficient condition that these vectors shall neutralize are

$$\begin{aligned} a'_1 \quad &+ a'_2 \quad + a'_3 \quad = 0, \\ b'_1 \quad &+ b'_2 \quad + b'_3 \quad = 0, \\ (a_1 - b_1) &+ (a_2 - b_2) + (a_3 - b_3) = 0. \end{aligned}$$

To prove this we are to remember that the accented quantities being all small, their products may be neglected. The unaccented quantities are also very nearly equal to a constant: the actual value of the constant being arbitrary, we may take it to be unity.

The co-ordinates of any arbitrary point being taken, x_1, x_2, x_3, x_4, the effect of the first vector is to carry that point to a position of which the co-ordinates are

$$\begin{aligned} &a_1 x_1 + a'_1 x_2, \\ &b'_1 x_1 + b_1 x_2, \\ &b_1 x_3 - b'_1 x_4, \\ -&a'_1 x_3 + a_1 x_4. \end{aligned}$$

The effect of the second vector is to translate this point to a new position, of which the co-ordinates are

$$\begin{aligned} &a_1 a_2 x_1 + a'_1 x_2 + a'_2 x_2, \\ &b_1 b_2 x_2 + b'_1 x_1 + b'_2 x_1, \\ &b_1 b_2 x_3 - b'_1 x_4 - b'_2 x_4, \\ &a_1 a_2 x_4 - a'_1 x_3 - a'_2 x_3. \end{aligned}$$

The effect of the third vector, applied to the point which has already been twice deranged, is to convey it to the position of which the three co-ordinates are

$$\begin{aligned} &a_1 a_2 a_3 x_1 + x_2 (a'_1 + a'_2 + a'_3), \\ &b_1 b_2 b_3 x_2 + x_1 (b'_1 + b'_2 + b'_3), \\ &b_1 b_2 b_3 x_3 - x_4 (b'_1 + b'_2 + b'_3), \\ &a_1 a_2 a_3 x_4 - x_3 (a'_1 + a'_2 + a'_3). \end{aligned}$$

If the three vectors are to neutralize, then this point must coincide with x_1, x_2, x_3, x_4. The conditions for this are

$$\begin{aligned} a'_1 + a'_2 + a'_3 &= 0, \\ b'_1 + b'_2 + b'_3 &= 0, \\ a_1 a_2 a_3 &= b_1 b_2 b_3. \end{aligned}$$

The last condition may, however, be transformed for

$$a_1 a_2 a_3 = (1 + \overline{a_1 - 1})(1 + \overline{a_2 - 1})(1 + \overline{a_3 - 1}) = 1 + a_1 - 1 + a_2 - 1 + a_3 - 1,$$

if we neglect the products of the small quantities. The last equation, therefore, reduces to the form

$$\overline{a_1 - b_1} + \overline{a_2 - b_2} + \overline{a_3 - b_3} = 0.$$

Given the co-ordinates of two vectors a_1, b_1, a'_1, b'_1 *and* a_2, b_2, a'_2, b'_2, *it is required to determine the angle between them.*

By the angle between two vectors we are, of course, to understand the angle between the two directions in which any point would be moved if it received a displacement by either one vector or the other.

To investigate the above problem we may take any point arbitrarily. I select the point of which the co-ordinates are

$$0,\ a_2,\ \ 0,\ a_4.$$

The polar plane of this point with regard to the quadric is

$$a_2 x_4 + a_4 x_2 = 0.$$

In this plane we first find the two points θ and ϕ, which are defined to be the points in that plane towards which the vectors will displace a. It easily appears that

$$\begin{aligned}
\theta_1 &= \quad 2a'_1 a_2; & \phi_1 &= \quad + 2a'_2 a_2,\\
\theta_2 &= (b_1 - a_1) a_2; & \phi_2 &= (b_2 - a_2) a_2,\\
\theta_3 &= \quad - 2b'_1 a_4; & \phi_3 &= \quad - 2b'_2 a_4,\\
\theta_4 &= (a_1 - b_1) a_4; & \phi_4 &= (a_2 - b_2) a_4.
\end{aligned}$$

It can easily be shown that the required angle is equal to the distance between the points θ and ϕ. To find the distance we substitute in the equation of the quadric $\lambda\phi_1 + \omega\theta_1$, &c., and we thus obtain

$$\lambda^2(\phi_1\phi_3 + \phi_2\phi_4) + \lambda\mu\,(\theta_1\phi_3 + \phi_1\theta_3 + \theta_2\phi_4 + \phi_2\theta_4) + \mu^2(\theta_1\theta_3 + \theta_2\theta_4) = 0.$$

Denoting for a moment this equation by

$$A\lambda^2 + 2B\lambda\mu + C\mu^2 = 0,$$

we have for the required angle ω the expression

$$\omega = m \log \frac{+B + \sqrt{B^2 - AC}}{+B - \sqrt{B^2 - AC}},$$

where m is a constant depending upon the units employed. To simplify the expression,

Let $$B = \rho \cos \epsilon,$$

$$\sqrt{B^2 - AC} = i\rho \sin \epsilon,$$

$$\omega = m \log \frac{\cos \epsilon + i \sin \epsilon}{\cos \epsilon - i \sin \epsilon} = m \log e^{2i\epsilon}.$$

If we make $m = -\frac{i}{2}$, then we have

$$\cos \omega = \frac{B}{\sqrt{AC}}.$$

Introducing the values for B, A, C, and then substituting for θ, &c., ϕ, &c., we have, finally,

$$\cos \omega = \frac{2a'_1b'_2 + 2a'_2b'_1 + (a_1 - b_1)(a_2 - b_2)}{\sqrt{(a_1 - b_1)^2 + 4a'_1b'_1}\,\sqrt{(a_2 - b_2)^2 + 4a'_2b'_2}}.$$

If the numerator of the value of cos ω vanish, then we have the condition already found that the two vectors shall be at right angles. If either of the factors of the denominator vanish—if, for example,

$$(a_1 - b_1)^2 + 4a'_1b'_1 = 0,$$

then the length of the vector is zero, and its direction of course becomes indeterminate.

We have also the very useful result that the expression

$$2a'_1b'_2 + 2a'_2b'_1 + (a_1 - b_1)(a_2 - b_2)$$

denotes the product of the lengths of the two vectors multiplied into the cosine of the angle between the two vectors.

Composition of two Vectors.—Given two vectors of lengths α and β, which are inclined together at an angle α, it is required to determine the length of a vector γ which is equivalent to their joint effect.

Let the co-ordinates of α and β be a_1, b_1, a'_1, b'_1, and a_2, b_2, a'_2, b'_2, respectively, and let the co-ordinates of γ be a_3, b_3, a'_3, b'_3. Then (omitting a common factor) we have

$$\alpha^2 = (a_1 - b_1)^2 + 4a'_1b'_1,$$

$$\beta^2 = (a_2 - b_2)^2 + 4a'_2b'_2,$$

$$\gamma^2 = (a_3 - b_3)^2 + 4a'_3b'_3:$$

we have also

$$a_3 - b_3 = (a_1 - b_1) + (a_2 - b_2),$$

$$a'_3 = a'_1 + a'_2,$$

$$b'_3 = b'_1 + b'_2;$$

and also

$$(a_1 - b_1)(a_2 - b_2) + 2a'_2b'_1 + 2a'_2b'_1 = \alpha\beta \cos\theta.$$

$$\gamma^2 = [(a_1 - b_1)^2 + (a_2 - b_2)]^2 + 4(a'_1 + a'_2)(b'_1 + b'_2),$$

$$= (a_1 - b_1)^2 + 4a'_1b'_1,$$

$$+ (a_2 - b_2)^2 + 4a'_2b'_2,$$

$$+ 2(a_1 - b_1)(a_2 - b_2) + 4a'_2b'_1 + 4a'_1b'_2;$$

whence, finally,

$$\gamma^2 = \alpha^2 + \beta^2 + 2\alpha\beta \cos\theta.$$

It is extremely remarkable to find that we have for the composition of vectors in elliptic space precisely the same equation as is so familiar in ordinary space.

If a vector of length γ be decomposed into two coplanar and rectangular vectors inclined to γ at angles θ and $90 - \theta$, it is required to determine the components α and β.

Using the notation already adopted, we have

$$\gamma \cos\theta = \frac{(a_1 - b_1)(a_3 - b_3) + 2a'_3 b'_1 + 2a'_1 b'_3}{\sqrt{(a_1 - b_1)^2 + 4a'_1 b'_1}};$$

but we have

$$a_3 - b_3 = (a_1 - b_1) + (a_2 - b_2),$$

$$a'_3 = a'_1 + a'_2,$$

$$b'_3 = b'_1 + b'_2;$$

whence, observing that

$$(a_1 - b_1)(a_2 - b_2) + 2a'_1 b'_2 + 2b'_1 a'_2 = 0,$$

we have

$$\gamma \cos\theta = \sqrt{(a_1 - b_1)^2 + 4a'_1 b'_1} = \alpha.$$

It is thus seen that the general theory of the composition of vectors in elliptic space can be regarded as identical with the theory of the composition of vectors in ordinary space, so far, at least, as the formulæ are concerned by which the results are to be expressed.

The Motor.—The most general displacement of a rigid system in elliptic space consists of a rotation α about one line followed by a rotation β about the conjugate polar of that line. We shall consider the amplitudes of both these rotations to be small quantities. The two movements taken together constitute what Clifford has termed a motor. It will first of all be necessary to set forth the conception in elliptic space, which is the homologue of the conception of *pitch* in the Theory of Screws in ordinary space. The pitch can most conveniently be expressed by the function

$$p = \frac{2\alpha\beta}{\alpha^2 + \beta^2}.$$

If either α or β vanish, then the pitch becomes zero. The motor then degenerates to a pure rotation about one or other of the two conjugate

polars. This, of course, agrees with the ordinary conception of the pitch, which is zero whenever the general screw motion of the rigid body degrades to a pure rotation.

In ordinary space we have

$$p\alpha = d\beta,$$

where β is zero and where d is infinite. In this case

$$\frac{2\alpha\beta}{\alpha^2 + \beta^2} = 2\frac{\beta}{\alpha} = 2\frac{p}{d},$$

i. e. the pitch is proportional to the function now under consideration.

No generality will be sacrificed by the use of a single symbol to express the pitch. We may make $\alpha = \cos\theta$ and $\beta = \sin\theta$; the pitch then assumes the very simple form $\sin 2\theta$. We thus see that the pitch can never exceed unity.

If the motor be a vector, then we have $\beta = \pm\alpha$, or $\theta = \pm 45°$, and the pitch is simply ± 1.

It should be noticed that a rotation α about the line A, and a rotation β about its conjugate polar B, constitute a motor of the same pitch as a rotation β about A and α about B.

Right and left Vectors.—Before going further it will be necessary to discuss some of the relations between right and left vectors. A right vector will displace any point P in a certain direction PA; a left vector will displace the same point in the direction PB. It will, of course, usually happen that the directions PA and PB are not identical. It is, however, of great importance to observe that when P is situated on either of two rays then the directions of displacement are identical. To determine these two rays we draw the two pairs of generators corresponding to the two vectors. As these generators belong to opposite systems, they will form four edges of a tetrahedron. The two remaining edges are a pair of conjugate polars, and they form the two rays of which we are in search. The proof is obvious: a point P on one of these rays must be displaced along the same ray by either of the vectors, for this ray intersects both of the generators which define that vector.

Let a right vector consist of rotations $+\alpha$, $+\alpha$ about two conjugate polars, and let a left vector consist of rotations $+\alpha$, $-\alpha$, also about two conjugate polars. Without loss of generality we may take the two conjugate polars in both cases to be the pair just determined.

Let OO' and PP' be the conjugate polars. The right vector is appropriate to the generators OP and $O'P'$. The left vector to the generators OP' and $O'P$. If we take the intersections with the absolute in the order OO' for A, then we must take them in the order PP' if we are considering a right vector, and in the order $P'P$ if we are considering a left vector. This is obvious, for in the first case we take the intersections of the conjugate polar with the generators OP and $O'P'$. In the second case we take the intersection of the conjugate polar with OP' and $O'P$.

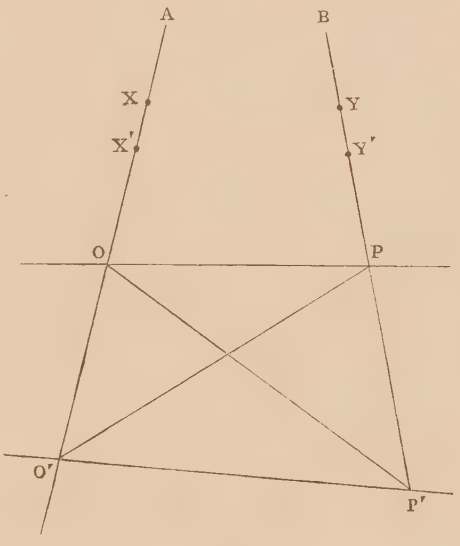


Fig. 4.

If, therefore, the vector be right, we have for the displacements of X and Y,

$$c \log (XX'OO') = c \log (YY'PP').$$

If, however, the vector be left, then Y must be displaced to a distance Y_0, defined by

$$c \log (XX'OO') = c \log (YY_0P'P):$$

we therefore have

$$c \log (YY'PP') = c \log (YY_0P'P);$$

but from an obvious property of the logarithms,

$$c \log (YY_0P'P) = - c \log (YY_0PP');$$

whence, finally,

$$c \log (YY'PP') = - c \log (YY_0PP').$$

We hence have the important result, that the distance through which a point

on one of the common conjugate polars is displaced by one of two heteronymous vectors of equal amplitude, merely differs in sign from the displacement which the same point would receive from the other vector.

The Conception of Force in Elliptic Space.

Fundamental Principles.—In ordinary space we are quite familiar with the perfect indentity which subsists between the composition of small rotations and the composition of forces. We shall now learn that what we so well know in ordinary space is but the survival, in an attenuated form, of a much more complete theory in elliptic space. We have in elliptic space force-motors and force-vectors, just as we have displacement-motors and displacement-vectors. We shall base the Dynamical theory on an elementary principle in the theory of Energy. Suppose that a force of intensity f act on a particle which is displaced in a direction directly opposed to the force through a distance δ, then the quantity of work done is denoted by $f\delta$.

Suppose a system be acted upon by a force vector λ, and that the system receive a small displacement, denoted by the vector μ. It is required to determine the work done if the angle between the two vectors be θ.

Take any two points P and Q, and draw through P and Q lines parallel to each of the vectors. Two of these lines correspond to the forces and two to the displacements. The work done is, therefore,

$$2\lambda\mu \cos\theta.$$

This result can be very simply expressed in terms of the co-ordinates of the vectors; for, from the formulæ already obtained, it is obviously

$$(a_1 - b_1)(a_2 - b_2) + 2a'_1 b'_2 + 2a'_2 b'_1.$$

Neutrality of heteronymous Vectors.—We are now able to demonstrate a very important theorem which lies at the foundation of all the applications of Dynamics in elliptic space. The virtual moment of a force-vector and

a displacement-vector will always vanish when the vectors are homonymous and rectangular. The analogies of ordinary geometry would have suggested this result, and we have found it to be true. If, however, the two vectors be not homonymous, the result is extremely remarkable. The two vectors must then be neutral under all circumstances.

The proof of this singular proposition is very simple. Let the two vectors be what they may, we can always find one pair of conjugate polars which belong to them both. Let the two forces be λ, λ on the two conjugate polars, and let the displacements be μ, $-\mu$, then the work done is

$$\lambda\mu - \lambda\mu = 0.$$

It seems at first sight incredible that a theorem demonstrated with such simplicity should be of such extreme significance. It is not too much to say that the theory of Rigid Dynamics in elliptic space will, to a large extent, flow from this simple result.

Decomposition of a Motor into a pair of Vectors.—Clifford has proved the very important result that a motor can always be decomposed in one way into a right vector and a left vector. Let α and β be the rotations on the two conjugate polars. If on these conjugate polars we take a right vector with amplitudes

$$+\tfrac{1}{2}(\alpha+\beta), \qquad +\tfrac{1}{2}(\alpha+\beta),$$

and on the same two conjugate polars a left vector with the amplitudes

$$\tfrac{1}{2}(\alpha-\beta), \qquad -\tfrac{1}{2}(\alpha-\beta),$$

then it is obvious that these two vectors are jointly equivalent to the given motor.

Decomposition of a Motor into six Standard Vectors.—We can first decompose the motor into two right and left vectors; we then decompose each of these vectors into vector components along three standard vectors. It will usually be convenient to take the standard vectors mutually rectangular; we shall then have the original motor resolved into six component vectors whereof every pair are neutral. These may be regarded as the vector co-ordinates of the motor.

Neutrality of two Motors.—Let it be required to determine the condition that a force-motor and a displacement-motor be neutral. By this we mean, that if a rigid body were acted upon by the force-motor, and were displaced by the displacement-motor, yet no work would be done. Let $\alpha_1 \ldots \alpha_6$ denote the co-ordinates of the force-motor when the intensity of the motor is unity. Let $\beta_1 \ldots \beta_6$ denote the co-ordinates of the displacement-motor for a displacement of unit amplitude. The intensity (or amplitude) of a wrench (or twist) about any motor may be taken to be $\sqrt{\lambda^2 + \mu^2}$ where λ and μ are the rotations about the two conjugate polars. If, therefore, the intensity of a vector be x, the intensities of the components are $x \div \sqrt{2}$. If the intensity be α'', and the amplitude be β', then the expression for the work done is

$$\alpha''\beta' (\alpha_1\beta_1 + \&c. + \alpha_6\beta_6).$$

If the two motors be neutral this expression must vanish, and consequently the function under the brackets must be equal to zero.

Reciprocal Motors.—When the co-ordinates of two motors fulfil the condition

$$\alpha_1\beta_1 + \&c. + \alpha_6\beta_6 = 0,$$

then these two motors possess the important property that a displacement about either does no work against a force system on the other. It will be very convenient to use the words *twist* and *wrench*, which are used in the Theory of Screws to denote the analogous conceptions in elliptic space. The word *motor* may then be conveniently employed to designate the pair of conjugate polars and their appropriate pitch. We thus have a theory of reciprocal motors which is exactly analogous to the theory of reciprocal screws.

Work done in a Twist against a Wrench on the same Motor.—If the pitch of the motor be $\sin 2\theta$, then the components of the twist α' are $\alpha' \sin\theta$ and $\alpha' \cos\theta$. The components of the wrench β'' are $\beta'' \sin\theta$ and $\beta'' \cos\theta$. The rotation $\alpha' \sin\theta$ about one polar will displace a point on the other through a distance $\alpha' \sin\theta$; the work done will, therefore, be

$$\alpha'\beta'' \sin\theta \cos\theta.$$

In a similar way the rotation $\alpha' \cos\theta$ will do an amount of work

$$\alpha'\beta'' \sin\theta \cos\theta.$$

The total work done is the sum of these two equal parts, and may therefore be expressed in the extremely simple form

$$\alpha' . \beta'' . p.$$

We may thus have, as it were, a physical definition of the pitch of a motor. It would be the work done in a unit twist about that motor against a unit wrench on the same motor.

These results are merely the generalizations for elliptic space of familiar results in the Theory of Screws. One point, however, should be noticed. If in ordinary space a twist of amplitude α' be effected against a wrench of intensity β'' on the same screw, the expression for the work is

$$2\alpha'\beta'' p.$$

The presence of the factor 2 in the one case, and not in the other, demands explanation. The difference is apparent rather than real. It arises from the different definitions of intensity which are required for the two spaces. In ordinary space we express the amplitude of the twist by the rotation around one axis. In elliptic space it is preferable to use for the amplitude the square root of the sum of the squares of the two rotations.

In the Theory of Screws it has been shown that there is a certain reciprocal function of the screws which, when the two screws coincide, degrades to the pitch. This function is called the *virtual coefficient*. It may be defined to be the work done when the body receives a twist of unit amplitude around one screw against a wrench of unit intensity on the other screw. This function is identical whichever of the screws be chosen for the wrench. The evanescence of this function is the condition that the two screws be neutral. The virtual coefficient is in many respects analogous to the cosine of the angle between a pair of ordinary intersecting lines.

To determine the virtual coefficient of the two motors in elliptic space in terms of the co-ordinates of the two motors is a problem we have already solved. It remains now to discuss the form of this function when expressed

geometrically as the extension to elliptic space of the well-known expression,

$$(p_\alpha + p_\beta)\cos\theta - d\sin\theta,$$

which is so familiar in the Theory of Screws.

In ordinary space we can determine the mutual position of two rays by the angle between them, combined with their shortest distance apart. It is one of the most curious points in the whole of the elliptic geometry to observe that this very unsymmetrical way of expressing the relation is but a degraded form of a process which has perfect symmetry. Take any two rays, A and B, and their two conjugate polars, A' and B': across these four rays two common transversals, X and Y, can be drawn. Each of these transversals intersects A and B at right angles. We thus have two common perpendiculars to A and B. The lengths of these two perpendiculars are in general different: let us denote them by x and y. It will now be convenient to employ x and y to denote the relative position of the two right lines. If we degrade to ordinary space, one of these perpendiculars goes to infinity, and its length represents the angle between the two lines, measured in the ordinary manner. We are at once reminded of the proposition in Spherical Geometry, that the common perpendicular to two great circles expresses also the angle between those circles.

It is manifest that the virtual coefficient of the two motors of which we are in search must be capable of expression by means of the pitches of the two motors and their common perpendiculars.

Let f be the intensity of a motor-wrench which has the components $f\cos\alpha$ and $f\sin\alpha$ on the conjugate polars AA' and on BB'.

Let ω be the amplitude of a motor-twist which has components $\omega\cos\beta$ and $\omega\sin\beta$ on the conjugate polars CC' and on DD'.

The wrench may be decomposed into a right vector of intensity $\frac{1}{\sqrt{2}} f\sin(\alpha+45°)$, and a left vector of intensity $\frac{1}{\sqrt{2}} f\cos(\alpha+45°)$.

The twist can be similarly decomposed with a right vector of amplitude $\frac{1}{\sqrt{2}}\omega\sin(\beta+45°)$, and a left vector $\frac{1}{\sqrt{2}}\omega\cos(\beta+45°)$.

The two right vectors, and also the two left vectors, are now to be compounded.

Let AA' and BB' be a pair of conjugate polars. Let AB and $A'B'$ be a pair of conjugate polars which intersect AA' and BB'.

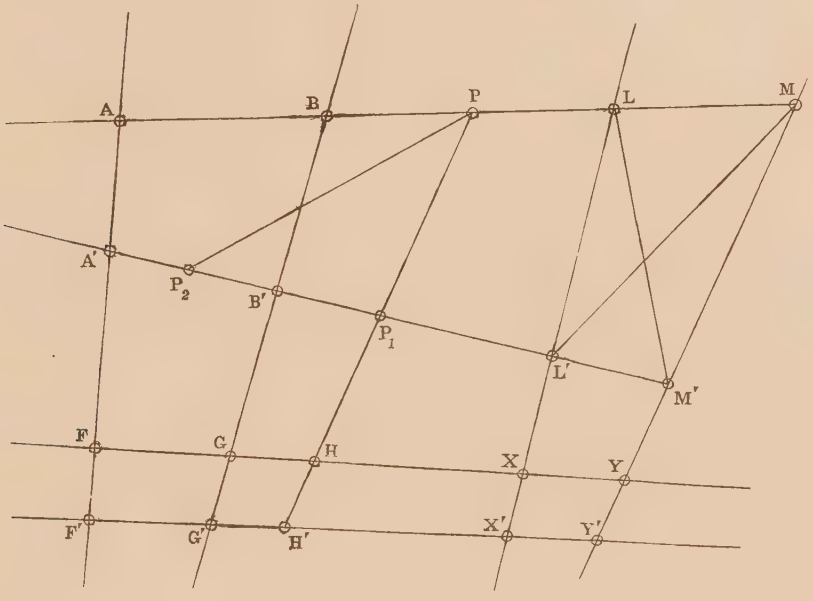


Fig. 5.

Let P be any point through which right and left parallels PP_1 and PP_2 are drawn to AA' (and to BB', which is, of course, both a right and left parallel to its conjugate polar).

We must first show that PP_1 intersects $A'B'$. Let FG and $F'G'$ be the pair of right generators determining the right system of parallels, then FF' being the intersections of AA' with the quadric, we have AA' and FF' dividing each other harmonically, and hence

$$(AA'FF') = (BB'GG').$$

It is therefore obvious that an hyperboloid could be drawn, of which AB, $A'B'$, FG and $F'G'$ are all generators: PHH' is a generator of the other system, and must consequently intersect $A'B'$.

It can be shown by similar reasoning that P_2 lies on $A'B'$, only in this case the pair of generators determining the parallels will be FG and $F'G'$.

The rays AB and $A'B'$ intersect the quadric in the points LM and $L'M'$. Let LL' and MM' be two generators which intersect FG and $F'G'$. Then since AB, $A'B'$, FG, $F'G'$ are four generators of one system on an hyperboloid, while AA', BB', PP_1, LL', MM' are four generators of the other system on the same hyperboloid, we have, obviously, the following anharmonic equality :—

$$(BPLM) = (B'P_1L'M')$$

The equations of these anharmonic ratios are equal to the distances BP and $B'P'$, and thus we obtain the very remarkable result, that

$$BP = B'P_1.$$

We should, of course, in the same way find

$$BP = B'P_2.$$

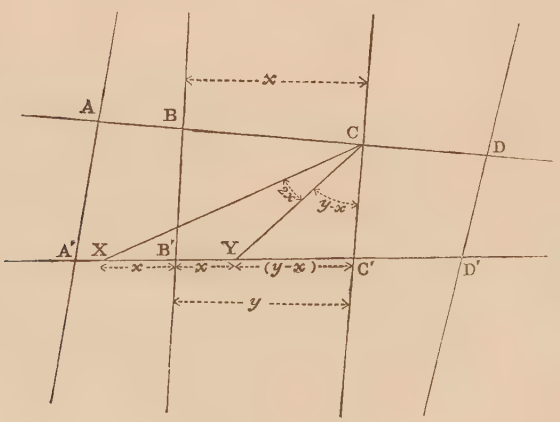


Fig. 6.

Draw through CD the two parallels CX and CY to the pair of conjugate polars AA' and BB'.

If CX be the right parallel to AA', then for the right vectors we have

$$f\omega \sin(\alpha + 45°) \sin(\beta + 45°) \cos(y + x),$$

and for the left vectors

$$-f\omega \cos(\alpha + 45°) \cos(\beta + 45°) \cos(y - x):$$

uniting these two expressions, we have for the work done,

$$f\omega [\cos x \cos y \sin(\alpha + \beta) - \sin x \sin y \cos(\alpha - \beta)].$$

The expression within the brackets is the virtual coefficient of the two motors.

If one motor be a right vector, and the other be a left vector, then

$$x = 0; \quad y = 0; \quad \beta = \alpha.$$

The formula reduces to

$$f\omega \sin 2\alpha = f\omega \times \text{pitch},$$

a result already obtained.

If the motors be a right and left vector,

$$\alpha = 45°; \quad \beta = -45°,$$

and the expression vanishes, as it ought.

In ordinary space if $\sin \alpha$, $\sin \beta$ be two rotations round the axes at infinity, α and β must be very small. x is of course the distance, and y is the angle. The expression reduces to the well-known form of the virtual coefficient,

$$(a + b) \cos\theta - d \sin\theta.$$

The condition that two motors should be reciprocal has therefore the very simple form,

$$\cos x \cos y \sin(\alpha + \beta) - \sin x \sin y \cos(\alpha - \beta) = 0.$$

The Theory of Screws has been shown to depend, to a great extent, on the properties of Reciprocal Screws. We have now taken the step which will enable the Geometrical theory of the Dynamics of a Rigid System in Elliptic Space to be opened up on lines parallel to those followed in the Theory of Screws in ordinary space. The development of this subject promises to be one of some extent, and the present communication is only to be regarded as introductory to the general theory.

X.—*On some Deductions from M'Cullagh's Lectures on Rotation.* By Francis A. Tarleton, LL.D., F.T.C.D.

[Read, February 27, 1882.]

The recent publication of Professor M'Cullagh's works in a collected form having drawn the attention of the scientific world to results long since given by him, some remarks on his Lectures on Rotation, and one or two results readily deducible from them, may be of some interest to the Members of the Academy.

Deduction of Poinsot's Equation from M'Cullagh's Equation.

In considering the motion of a rigid body round a fixed point under the action of no forces, Poinsot gives an equation for the angular velocity with which the plane containing the momentum axis and the instantaneous axis of rotation of the body turns round the momentum axis.

Poinsot's equation is usually written in the form—

$$\frac{dv}{dt} = \frac{T}{G} + \frac{(AT - G^2)(BT - G^2)(CT - G^2)}{ABCGT^2} \cot^2 \phi ;$$

where v is the angle which the plane containing the momentum axis and instantaneous axis of rotation makes with a fixed plane through the momentum axis, ϕ the angle between the momentum axis and axis of rotation; A, B, C the principal moments of inertia of the body; T its *vis viva*, and G its moment of momentum, or the magnitude of the impulsive couple which would impart to it its actual velocity.

M'Cullagh proves the equation $r^2 \frac{dv}{dt} = \frac{G}{M}$, where M is the mass of the body, and r the intercept cut off by the ellipsoid on the centrifugal couple axis.

If R be the intercept on the momentum axis made by the ellipsoid of gyration, p the perpendicular on the tangent plane at the extremity of R, and ω the angular velocity of the body, the following equations are either proved by M'Cullagh or are immediately obvious:—

$$T = Mp^2\omega^2, \qquad \frac{G}{M\omega} = Rp, \qquad A = Ma^2, \qquad B = Mb^2,$$

$$C = Mc^2, \qquad R\cos\phi = p, \qquad \frac{T}{G} = \omega\cos\phi, \qquad \frac{G}{M} = \omega\cos\phi\, R^2.$$

If we make the substitution indicated by the last of these in M'Cullagh's equation, it becomes $\frac{dv}{dt} = \frac{R^2}{r^2}\omega\cos\phi$; whilst, by means of those indicated by the former, Poinsot's equation assumes the following form:—

$$\frac{dv}{dt} = \omega\cos\phi\left\{1 + \frac{(a^2-R^2)(b^2-R^2)(c^2-R^2)}{a^2b^2c^2}\cot^2\phi\right\}.$$

In this shape it is easily deduced from M'Cullagh's equation, as follows: The axes of a central section of the quadric abc are parallel to the normals to the two confocals through the extremity of the semi-diameter D conjugate to the section, and (a', a'' being the semi-axes of the confocals) are given by the equations $R^2 = a^2 - a'^2$, $r^2 = a^2 - a''^2$ (Salmon, *Geometry of Three Dimensions*, §§ 163, 164). Moreover, if r' be an axis of the section conjugate to D in the quadric a', the direction of r' coincides with that of r, each being normal to a'', and the magnitude of r' is given by the equation $r'^2 = a'^2 - a''^2$; whence $r'^2 = r^2 - R^2$.

Again, if p' be the perpendicular on the tangent plane to a', which is parallel to the plane of D and r', or r, the direction of p' coincides with that of p, and α, β, γ being the angles which this common direction makes with

the axes, $p'^2 = a'^2 \cos^2\alpha + b'^2 \cos^2\beta + c'^2 \cos^2\gamma = p^2 - R^2$, since $a'^2 = a^2 - R^2$, $b'^2 = b^2 - R^2$, $c'^2 = c^2 - R^2$.

Now, if ψ be the angle between D and the direction of r or r', we have from the quadric a, $D^2 = \dfrac{a^2 b^2 c^2}{r^2 p^2 \sin^2\psi}$, and from the quadric a', $D^2 = \dfrac{a'^2 b'^2 c'^2}{r'^2 p'^2 \sin^2\psi}$. Equating the two expressions for D^2, and substituting for a'^2, b'^2, c'^2, r'^2, p'^2, their values already given, we obtain

$$\frac{a^2 b^2 c^2}{r^2 p^2} = \frac{(a^2 - R^2)(b^2 - R^2)(c^2 - R^2)}{(R^2 - r^2)(R^2 - p^2)};$$

but
$$\frac{p^2}{R^2 - p^2} = \cot^2\phi,$$

whence
$$\frac{R^2 - r^2}{r^2} = \frac{(a^2 - R^2)(b^2 - R^2)(c^2 - R^2)}{a^2 b^2 c^2} \cot^2\phi,*$$

or
$$\frac{R^2}{r^2} = 1 + \frac{(a^2 - R^2)(b^2 - R^2)(c^2 - R^2)}{a^2 b^2 c^2} \cot^2\phi:$$

substituting, in M'Cullagh's equation, it becomes

$$\frac{dv}{dt} = \omega \cos\phi \left\{1 + \frac{(a^2 - R^2)(b^2 - R^2)(c^2 - R^2)}{a^2 b^2 c^2} \cot^2\phi\right\},$$

which is Poinsot's equation in its second form.

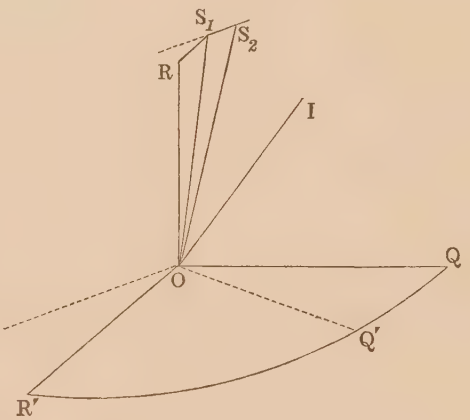
M'Cullagh's Second Mode of expressing the Motion of the Instantaneous Axis in Space.

The momentum-axis describes during the motion a cone in the body, which meets the ellipsoid of gyration in a spherical conic. If we draw lines at right angles to the tangent planes of this cone we obtain the reciprocal cone. The motion of the body in space is elegantly represented by

* The proof here given of this equation is believed to be new, but the equation itself is to be found in Salmon's *Geometry of Three Dimensions*, § 499.

M'Cullagh by means of the rolling and slipping of this latter cone, supposed to be rigidly attached to the body on the invariable plane. In the equation which expresses the result of these motions M'Cullagh would seem to have prefixed a wrong sign to the second term of the right-hand member. The equation in question may be investigated as follows:—

The velocity of rotation of the body round the instantaneous axis may, at each instant, be resolved into two components, one round the momentum axis OR, the other round the line at right angles to the momentum axis OR, and the centrifugual couple axis OR' (this line OQ being in the same plane with the momentum axis and instantaneous axis of rotation).



Suppose the cone C, which the different positions of the momentum axis trace out in the body, to be rigidly attached to the body, as also the reciprocal cone C'. Let OI, lying in the plane ROQ, be the instantaneous axis of rotation, and call $d\epsilon$ the angle between two consecutive tangent planes to the cone C, which will likewise be the angle between two consecutive edges of the cone C'. Let OS_1, OS_2, be edges of the cone C consecutive to OR. Let us suppose the rotation round OI to be counter-clockwise; its component round OQ will be counter-clockwise also, and will bring OS_1 to coincide with OR, and move the tangent plane $OS_1 S_2$ to C, in a direction parallel to OR'. The next rotation will then be effected round a line OQ' at right angles to $OS_1 S_2$ nearer than OQ to OR'.

Thus the motion in the invariable plane of the perpendicular to the plane of the momentum axis and centrifugal couple axis, in consequence of a counter-clockwise rotation round its successive positions, will be *clockwise*. This motion may be regarded as a rolling of the cone C' on the invariable plane. Its amount is plainly $d\epsilon$.

The component of angular velocity round OR will (if the rotation round OR is, as supposed, counter-clockwise) cause OQ to rotate also in a *counter-*

clockwise direction. The velocity of this rotation is constant, being $\omega \cos \phi$.

On the whole, then, v having the same signification as before,

$$v = \int \omega \cos \phi \, dt - \int \frac{d\epsilon}{dt} \, dt.$$

If s be the arc of the spherical conic which the cone C' cuts on the sphere of radius R, $Rd\epsilon = ds$, whence we have

$$v = \omega \cos \phi t - \frac{s}{R}.$$

If the cone C' should be on the opposite side of the invariable plane from OI and OR, or, in other words, if the curvature of the cone C turned towards OI should be convex instead of concave, the two parts of the motion of OQ will have the same sign, in which case

$$v = \omega \cos \phi t + \frac{s}{R}.$$

The former case occurs when R is less than the mean axis of the ellipsoid of gyration; the latter, when it is greater.

M'Cullagh states the direct opposite of what is stated here.

The investigation just given shows, however, that his statement is incorrect.

This appears likewise from considering the relative magnitude of the axes of a central section of an ellipsoid as well as from Poinsot's equation. In fact, R and r being the semiaxes of a central section of an ellipsoid—if $R > b$, $r < b$, and if $R < b$, $r > b$, for $R^2 = a^2 - a'^2$, $r^2 = a^2 - a''^2$; whence $a'^2 = a^2 - R^2$, $a''^2 = a^2 - r^2$, and therefore $b'^2 = b^2 - R^2$, $b''^2 = b^2 - r^2$. Now, of the two quantities b'^2 and b''^2, one is always positive, the other negative; because the three confocals passing through the same point are an ellipsoid, a hyperboloid of one sheet, and a hyperboloid of two sheets; wherefore if

$$R < b, \; r > b, \text{ and } \frac{R^2}{r^2} < 1, \text{ if } R > b, \; r < b, \text{ and } \frac{R^2}{r^2} > 1.$$

Now, by M'Cullagh's first equation, $\frac{dv}{dt} = \frac{R^2}{r^2} \cdot \omega \cos\phi$; therefore if $R < b$, $\frac{dv}{dt} < \omega \cos\phi$, and the second term on the right hand side in his second equation must be negative if $R > b$, $\frac{dv}{dt} > \omega \cos\phi$, and the second term must be positive.

Poinsot's equation leads to the same result. In fact if $R < b$, $a^2 - R^2$ and $b^2 - R^2$ are each positive, but $c^2 - R^2$ is negative. Hence the second term in the value of $\frac{dv}{dt}$ is negative. On the other hand, if $R > b$, R likewise $> c$, and therefore $(b^2 - R^2)$, $(c^2 - R^2)$ are each negative, whilst $a^2 - R^2$ is positive; therefore the second term of $\frac{dv}{dt}$ is positive.

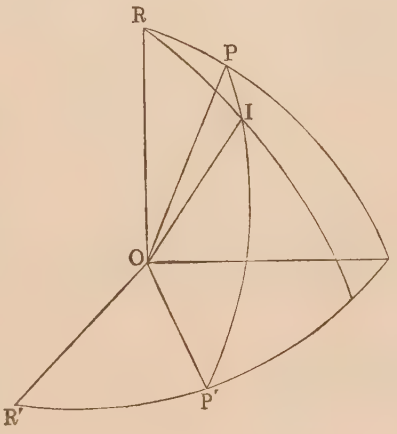
Motion in the Body of the Line perpendicular to the Plane of the Axis of Rotation and the Axis of Rotation due to Centrifugal Forces.

As an immediate consequence of the theorems already stated, it appears that the perpendicular to the plane of the instantaneous axis of rotation, and the corresponding axis of rotation due to centrifugal forces, traces out a line of curvature on the ellipsoid of gyration.

This is obvious if we consider that the instantaneous axis of rotation, and the axis of rotation due to centrifugal forces, are perpendiculars on the tangent planes at the extremities of R and r; hence a line perpendicular to them is conjugate both to R and r, and therefore meets the ellipsoid of gyration at its intersection with the confocals $a^2 - R^2$ and $a^2 - r^2$; but as R is constant, these points of intersection lie on the curve of intersection of the quadrics a^2 and $a^2 - R^2$, and therefore form a line of curvature on the ellipsoid of gyration.

Expression, by means of Elliptic Functions, of the Angle made by the Plane of the Momentum Axis and the Axis of Rotation, with a fixed Plane through the former, in terms of the Angle between these Axes.

M'Cullagh's mode of investigation, and the theorem in the theory of quadrics which has been already employed, enable us, without difficulty, to express the angle v in terms of ϕ.



OR being the momentum axis, OP the instantaneous axis of rotation at the beginning of the instant dt, PI its position at the end of the instant, OR' and OP' the positions of the axis of centrifugal couple and of the axis of rotation due to centrifugal forces at the beginning of the instant, we have

$$d\omega = \omega' \cos P'I = \omega' \cos PP' = \omega' \sin\phi \sin\phi',$$

where ϕ is angle ROP, and ϕ' angle $R'OP'$;

but as $\omega \cos\phi$ is constant, $\omega \sin\phi\, d\phi = \cos\phi\, d\omega$, and, by M'Cullagh's equation,

$$\omega' p' r = \omega^2 pR \sin\phi\, dt;$$

whence we obtain

$$(\text{as } r\cos\phi' = p', \quad R\cos\phi = p),$$

$$\frac{d\phi}{dt} = \omega \cos\phi \frac{R^2}{r^2} \sin\phi \cos\phi \tan\phi'.$$

By M'Cullagh's equation,

$$\frac{dv}{dt} = \omega \cos\phi \frac{R^2}{r^2};$$

whence

$$\frac{d\phi}{dt} = \frac{dv}{dt} \sin\phi \cos\phi \tan\phi'.$$

Now, by the theorem for quadrics already proved,

$$\frac{r^2}{R^2} = 1 + \frac{(a^2 - r^2)(b^2 - r^2)(c^2 - r^2)}{a^2 b^2 c^2} \cot^2 \phi',$$

and

$$\frac{R^2}{r^2} = 1 + \frac{(a^2 - R^2)(b^2 - R^2)(c^2 - R^2)}{a^2 b^2 c^2} \cot^2 \phi.$$

If we put

$$\frac{(a^2 - R^2)(b^2 - R^2)(c^2 - R^2)}{a^2 b^2 c^2} = \mu,$$

and substitute for $\tan \phi'$ by means of the first equation, and for r^2 by means of the second, we obtain

$$\frac{d\phi}{dt} = \frac{dv}{dt} \sin\phi \cos\phi \sqrt{\left(\frac{R^2 \left(a^2 - \frac{R^2}{1 + \mu \cot^2\phi}\right)\left(b^2 - \frac{R^2}{1 + \mu \cot^2\phi}\right)\left(c^2 - \frac{R^2}{1 + \mu \cot^2\phi}\right)}{\left(\frac{R^2}{1 + \mu \cot^2\phi} - R^2\right) a^2 b^2 c^2} \right)}$$

$$= \frac{dv}{dt} \frac{\sin^2\phi}{1 + \mu \cot^2\phi} \sqrt{\frac{(a'^2 + \mu a^2 \cot^2\phi)(b'^2 + \mu b^2 \cot^2\phi)(c'^2 + \mu c^2 \cot^2\phi)}{-\mu a^2 b^2 c^2}},$$

where

$$a'^2 = a^2 - R, \quad b'^2 = b^2 - R^2, \quad c'^2 = c^2 - R^2.$$

Let us now assume $\cot^2\phi = \eta$, and we get

$$dv = -\frac{1}{2} \frac{(1 + \mu\eta)\, d\eta}{\sqrt{U}},$$

where

$$U = \frac{(a'^2 + \mu a^2 \eta)(b'^2 + \mu b^2 \eta)(c'^2 + \mu c^2 \eta)\eta}{-\mu a^2 b^2 c^2} = -\left(\frac{a'^2}{\mu a^2} + \eta\right)\left(\frac{b'^2}{\mu b^2} + \eta\right)\left(\frac{c'^2}{\mu c^2} + \eta\right)\eta\mu^2.$$

Of the three quantities $\frac{a'^2}{\mu a^2}$, $\frac{b'^2}{\mu b^2}$, $\frac{c'^2}{\mu c^2}$, or

$$\frac{b^2 c^2}{(b^2 - R^2)(c^2 - R^2)}, \quad \frac{c^2 a^2}{(c^2 - R^2)(a^2 - R^2)}, \quad \frac{a^2 b^2}{(a^2 - R^2)(b^2 - R^2)},$$

two are always negative, and one positive, since $R^2 < a^2$, and $R^2 > c^2$. If

we call the negative ones $-\alpha$ and $-\beta$, and the positive, γ; α, β, γ, are all positive quantities; and if we suppose $\alpha > \beta$,

$$U = \mu^2(\alpha - \eta)(\eta - \beta)(\eta + \gamma)\eta,$$

whence

$$dv = -\frac{1}{2\mu}\frac{(1+\mu\eta)\,d\eta}{\sqrt{(\alpha-\eta)(\eta-\beta)(\eta+\gamma)\eta}} = -\frac{(1+\mu\eta)\,d\eta}{2\mu\sqrt{V}}.$$

The subsequent reduction of this to elliptic functions is effected in the usual manner.

If we assume $\eta = \frac{g+h\zeta}{1+\zeta}$, in order that the odd powers of ζ should vanish, we get to determine g and h the equations

$$2gh - (\alpha+\beta)(g+h) + 2\alpha\beta = 0,$$

$$2gh + \gamma(g+h) = 0;$$

whence it follows that g and h are the roots of the quadratic

$$x^2 - \frac{2\alpha\beta}{\alpha+\beta+\gamma}x - \frac{\alpha\beta\gamma}{\alpha+\beta+\gamma} = 0 = f(x).$$

Now α, β, γ are all positive, and $\alpha > \beta$, hence we find $f(\alpha)$ positive, $f(\beta)$ negative, $f(0)$ negative, $f(-\gamma)$ positive; wherefore if λ_1 and $-\lambda_2$ are the roots of $f(x) = 0$, λ_1 and λ_2 are both positive, $\lambda_1 > \beta$, $\lambda_1 < \alpha$, $\lambda_2 < \gamma$, $\lambda_1 - \lambda_2 = \frac{2\alpha\beta}{\alpha+\beta+\gamma} > 0$.

We have then

$$V = \frac{-1}{(1+\zeta)^4}\left\{[(\lambda_1-\alpha)(\lambda_1-\beta)+(\lambda_2+\alpha)(\lambda_2+\beta)\zeta^2][\lambda_1(\gamma+\lambda_1)-\lambda_2(\gamma-\lambda_2)\zeta^2]\right\}$$

$$= \frac{1}{(1+\zeta)^4}\left\{[(\alpha-\lambda_1)(\lambda_1-\beta)-(\lambda_2+\alpha)(\lambda_2+\beta)\zeta^2][\lambda_1(\gamma+\lambda_1)-\lambda_2(\gamma-\lambda_2)\zeta^2]\right\}.$$

Each factor of V is necessarily positive, being the product of two positive factors. Moreover,

$$\lambda_1(\gamma+\lambda_1) > \lambda_2(\gamma-\lambda_2),$$

but
$$(\alpha - \lambda_1)(\lambda_1 - \beta) - (\lambda_2 + \alpha)(\lambda_2 + \beta)$$
$$= (\alpha + \beta)\ \lambda_1 - \lambda_1^2 - \alpha\beta - \lambda_2^2 - (\alpha + \beta)\lambda_2 - \alpha\beta$$
$$= (\alpha + \beta)(\lambda_1 - \lambda_2) - 2\alpha\beta - \lambda_1^2 - \lambda_2^2$$
$$= (\alpha + \beta)(\lambda_1 - \lambda_2) - (\alpha + \beta + \gamma)(\lambda_1 - \lambda_2) - \lambda_1^2 - \lambda_2^2 < 0\ ;$$

therefore $(\alpha - \lambda_1)(\lambda_1 - \beta) < (\lambda_2 + \alpha)(\lambda_2 + \beta)$.

Hence, putting

$$q^2 = (\alpha - \lambda_1)(\lambda_1 - \beta), \qquad s^2 = (\lambda_2 + \alpha)(\lambda_2 + \beta),$$
$$q'^2 = \lambda_1(\gamma + \lambda_1), \qquad s'^2 = \lambda_2(\gamma - \lambda_2),$$

we have
$$V = \frac{1}{(1+\zeta)^4}\left\{(q^2 - s^2\zeta^2)(q'^2 - s'^2\zeta^2)\right\};$$

also
$$d\eta = -\frac{(\lambda_1 + \lambda_2)d\zeta}{(1+\zeta)^2},$$

and
$$1 + \mu\eta = 1 - \mu\lambda_2 + \frac{\mu(\lambda_1 + \lambda_2)}{1+\zeta}\ ;$$

whence
$$dv = \frac{\lambda_1 + \lambda_2}{2\mu}\left\{1 - \mu\lambda_2 + \frac{\mu(\lambda_1 + \lambda_2)}{1+\zeta}\right\}\frac{d\zeta}{\sqrt{\{(q^2 - s^2\zeta^2)(q'^2 - s'^2\zeta^2)\}}}.$$

If we now assume

$$\frac{s}{q}\zeta = \sin\theta, \quad k^2 = \frac{s'^2 q^2}{s^2 q'^2}, \quad n = -\frac{q^2}{s^2},$$

after multiplying the second term in the bracket above and below by $1 - \zeta$, we obtain

$$dv = \frac{\lambda_1 + \lambda_2}{2\mu s q'}\left\{1 - \mu\lambda_2 + \frac{\mu(\lambda_1 + \lambda_2)}{1 + n\sin^2\theta}\right\}\frac{d\theta}{\Delta(k,\theta)}$$

$$- \frac{(\lambda_1 + \lambda_2)^2}{2}\frac{\zeta\, d\zeta}{(1-\zeta^2)\sqrt{(q^2 - s^2\zeta^2)(q'^2 - s'^2\zeta^2)}}.$$

Reducing the last term in the usual way, we obtain finally,

$$v = \frac{\lambda_1 + \lambda_2}{2\sqrt{\{(\lambda_2+\alpha)(\lambda_2+\beta)(\lambda_1+\gamma)\lambda_1\}}}\left\{\frac{1-\mu\lambda_2}{\mu}F(k,\theta) + (\lambda_1+\lambda_2)\,\Pi(n,k,\theta)\right\}$$

$$- \frac{(\lambda_1+\lambda_2)^2}{4\sqrt{\{[(\lambda_2+\alpha)(\lambda_2+\beta)-(\alpha-\lambda_1)(\lambda_1-\beta)][\lambda_1(\gamma+\lambda_1)-\lambda_2(\gamma-\lambda_2)]\}}}\cdot\psi,$$

where
$$\sin\theta = \sqrt{\frac{(\lambda_2+\alpha)(\lambda_2+\beta)}{(\alpha-\lambda_1)(\lambda_1-\beta)}}\cdot\frac{\lambda_1-\cot^2\phi}{\lambda_2+\cot^2\phi},$$

$$k^2 = \frac{(\alpha-\lambda_1)(\lambda_1-\beta)\lambda_2(\gamma-\lambda_2)}{(\lambda_2+\alpha)(\lambda_2+\beta)\lambda_1(\gamma+\lambda_1)},$$

$$n = -\frac{(\alpha-\lambda_1)(\lambda_1-\beta)}{(\lambda_2+\alpha)(\lambda_2+\beta)} \text{ (whence } n \text{ lies between } -k^2 \text{ and } -1),$$

and

$$\sin\psi = \frac{2(s^2-q^2)(q'^2-s'^2)(\lambda_2+\cot^2\phi)^2 + (2s^2s'^2 - s^2q'^2 - q^2s'^2)\{2(\lambda_1+\lambda_2)\cot^2\phi - \lambda_1^2+\lambda_2^2\}}{(s^2q'^2-q^2s'^2)\{2(\lambda_1+\lambda_2)\cot^2\phi - \lambda_1^2+\lambda_2^2\}},$$

by which equations the angle which the plane of the momentum axis and axis of rotation makes with a fixed plane, through the momentum axis, is expressed in terms of the angle between the axis of rotation and the momentum axis.

Expression of the Angle between the Momentum Axis and Axis of Rotation in Terms of the Time.

Since
$$\frac{d\phi}{dt} = \omega\cos\phi\frac{R^2}{r^2}\cdot\sin\phi\cos\phi\tan\phi',$$

and
$$\frac{R^2}{r^2} = 1+\mu\cot^2\phi, \quad \omega\cos\phi = \frac{G}{MR^2},$$

$$\frac{d\phi}{dt} = \frac{G}{MR^2}\sin^2\phi\sqrt{\frac{(a'^2+\mu a^2\cot^2\phi)(b'^2+\mu b^2\cot^2\phi)(c'^2+\mu c^2\cot^2\phi)}{-\mu a^2b^2c^2}},$$

whence $$\frac{G}{MR^2}\,dt = \frac{-1}{2\mu}\,\frac{d\eta}{\sqrt{\{(\alpha-\eta)(\eta-\beta)(\eta+\gamma)\eta\}}};$$

and therefore, by transformations the same as those already employed,

$$\frac{G}{MR^2}\,t = \frac{\lambda_1+\lambda_2}{2\mu\sqrt{\{(\lambda_2+\alpha)(\lambda_2+\beta)(\lambda_1+\gamma)\lambda_1\}}}\,F(k,\theta),$$

where k, θ, λ_1, &c., are the same as before.

The expression of v in terms of ϕ, and of ϕ in terms of t, completes M'Cullagh's theory of the motion of the instantaneous axis of rotation in space.

XI.—*On Certain Definite Integrals.* By John C. Malet, M.A., Professor of Mathematics, Queen's College, Cork.

[Read, April 10, 1882.]

Section I.

The Definite Integrals which I treat of in the following Memoir, which are interesting from their connexion with a certain class of hyper-elliptic integrals, have not, I believe, been previously evaluated.

If we transform the integral

$$\int \frac{(A + B \sin^2\theta)\, d\theta}{\sqrt{(1 - k^2 \sin^2\theta)\,(1 - k_1^2 \sin^2\theta)\,(1 - k_2^2 \sin^2\theta)}}$$

by the well-known formula

$$\sin\theta = \frac{\cos\phi}{\sqrt{1 - k^2 \sin^2\phi}},$$

we find an integral with the same moduli, if these are connected by the relation

$$1 - k^2 = (1 - k_1^2)\,(1 - k_2^2),$$

one of the well-known conditions among the moduli for which the integral is reducible to elliptic functions.

Putting

$$\Delta(\theta) = \sqrt{(1 - k^2 \sin^2\theta)\,(1 - k_1^2 \sin^2\theta)\left(1 - \frac{k^2 - k_1^2}{1 - k_1^2} \sin^2\theta\right)},$$

we find for the given transformation

$$\frac{(A + B \sin^2\theta)\, d\theta}{\Delta(\theta)} = \frac{-1}{\sqrt{1 - k^2}} \cdot \frac{A + B - (Ak^2 + B) \sin^2\phi}{\Delta(\phi)}\, d\phi;$$

hence, integrating between 0 and $\frac{\pi}{2}$, we get

$$\int_0^{\frac{\pi}{2}} \frac{(C + D\sin^2\theta)\,d\theta}{\Delta(\theta)} = 0,$$

where

$$C = A(\sqrt{1-k^2} - 1) - B,$$

$$D = Ak^2 + B(\sqrt{1-k^2} + 1),$$

from which we find

$$C(\sqrt{1-k^2} + 1) + D = 0.$$

Hence we have

$$\int_0^{\frac{\pi}{2}} \frac{d\theta}{\Delta(\theta)} = \{\sqrt{1-k^2} + 1\} \int_0^{\frac{\pi}{2}} \frac{\sin^2\theta\, d\theta}{\Delta(\theta)},$$

a theorem due to Professor M. Roberts, and derived by him from the values of the above integrals in terms of elliptic functions, given in his tract "On the addition of Elliptic and Hyper-Elliptic Integrals," page 67.

Let us now consider the definite integral

$$\int_0^{\frac{\pi}{2}} \frac{(A + B\sin^2\theta)\log\delta(k,\theta)}{\Delta(\theta)}\, d\theta,$$

where $\Delta(\theta)$ retains the same meaning as before, and

$$\delta(k,\theta) = \sqrt{1 - k^2\sin^2\theta}.$$

Transforming by the same substitution as before, we find

$$\int_0^{\frac{\pi}{2}} \frac{(C + D\sin^2\theta)\log\delta(k,\theta)}{\Delta(\theta)}\, d\theta = \log\sqrt{1-k^2} \int_0^{\frac{\pi}{2}} \frac{A + B - (Ak^2 + B)\sin^2\theta}{\Delta(\theta)}\, d\theta,$$

in which

$$C = A(\sqrt{1-k^2} + 1) + B,$$

$$D = -Ak^2 + B(\sqrt{1-k^2} - 1).$$

Hence

$$C(\sqrt{1-k^2} - 1) = D;$$

and letting $C = 1$, we find the formula

$$\int_0^{\frac{\pi}{2}} \frac{\{1-(1-\sqrt{1-k^2})\sin^2\theta\}\log.\delta(k,\theta)}{\Delta(\theta)}\,d\theta = \log\sqrt{1-k^2}\int_0^{\frac{\pi}{2}}\frac{1-\sin^2\theta}{\Delta(\theta)}\,d\theta.$$

Now we have (see Roberts, p. 67),

$$\int_0^{\frac{\pi}{2}}\frac{1-\sin^2\theta}{\Delta(\theta)}\,d\theta = \frac{1}{\sqrt{1-k^2}}\left\{1-\frac{1}{1+\sqrt{1-k^2}}\right\}\int_0^{\frac{\pi}{2}}\frac{d\theta}{\sqrt{1-\lambda^2\sin^2\theta}},$$

where

$$\lambda^2 = \frac{k_1^2(k^2-k_1^2)}{(1-k_1^2)(1+\sqrt{1-k^2})}.$$

Hence, using Legendre's notation for elliptic functions, we have the formula

$$\int_0^{\frac{\pi}{2}}\frac{\{1-(1-\sqrt{1-k^2})\sin^2\theta\}\log\delta(k,\theta)}{\Delta(\theta)}\,d\theta = \frac{\log\sqrt{1-k^2}}{1+\sqrt{1-k^2}}F\left(\lambda,\frac{\pi}{2}\right),$$

where λ has the value given above.

Transforming in the same manner the integral

$$\int_0^{\frac{\pi}{2}}\frac{(A+B\sin^2\theta)\log\tan\theta}{\Delta(\theta)}\,d\theta,$$

we find

$$\int_0^{\frac{\pi}{2}}\frac{(C+D\sin^2\theta)\log\tan\theta}{\Delta(\theta)}\,d\theta = \log\sqrt{1-k^2}\int_0^{\frac{\pi}{2}}\frac{A+B-(Ak^2+B)\sin^2\theta}{\Delta(\theta)}\,d\theta,$$

where

$$C = A(1-\sqrt{1-k^2})+B,$$

$$D = -Ak^2 - B(\sqrt{1-k^2}+1);$$

and, as before, we find the formula

$$\int_0^{\frac{\pi}{2}}\frac{\{(1-\sqrt{1-k^2})\sin^2\theta-1\}\log\tan\theta}{\Delta(\theta)}\,d\theta = \log\sqrt{1-k^2}\int_0^{\frac{\pi}{2}}\frac{1-\sin^2\theta}{\Delta(\theta)}\,d\theta,$$

or

$$\int_0^{\frac{\pi}{2}} \frac{\{(1-\sqrt{1-k^2})\sin^2\theta - 1\}\log\tan\theta}{\Delta(\theta)}\,d\theta = \frac{\log\sqrt{1-k^2}}{1+\sqrt{1-k^2}}\,F\left(\lambda, \frac{\pi}{2}\right),$$

where λ has the same value as before.

This result may also be deduced as follows:—Transforming, as before, the integral

$$\int_0^{\frac{\pi}{2}} \frac{(A + B\sin^2\theta)\log\sin\theta}{\Delta(\theta)}\,d\theta,$$

we find

$$\sqrt{1-k^2}\int_0^{\frac{\pi}{2}} \frac{(A + B\sin^2\theta)\log\sin\theta}{\Delta(\theta)}\,d\theta$$

$$= \int_0^{\frac{\pi}{2}} \frac{A + B - (Ak^2 + B)\sin^2\theta}{\Delta(\theta)}\{\log\cos\theta - \log\delta(k,\theta)\}\,d\theta.$$

Now, let

$$A\sqrt{1-k^2} = A + B,$$

from which

$$-Ak^2 = B\{\sqrt{1-k^2} + 1\}.$$

Hence, transposing and dividing by $\sqrt{1-k^2}$, we find

$$\int_0^{\frac{\pi}{2}} \frac{\{(1-\sqrt{1-k^2})\sin^2\theta - 1\}\log\tan\theta}{\Delta(\theta)}\,d\theta$$

$$= \int_0^{\frac{\pi}{2}} \frac{\{1-(1-\sqrt{1-k^2})\sin^2\theta\}\log\delta(k,\theta)}{\Delta(\theta)}\,d\theta.$$

Hence, having deduced the value of either of the above definite integrals, we get that of the other.

Again, putting

$$\sqrt{1-k_1^2\sin^2\theta} = \delta(k_1, \theta), \quad \sqrt{1 - \frac{k^2-k_1^2}{1-k_1^2}\sin^2\theta} = \delta(k_2, \theta),$$

and, considering the integral

$$\int_0^{\frac{\pi}{2}} \frac{(A + B\sin^2\theta)\log\delta(k_1, \theta)}{\Delta(\theta)}\,d\theta,$$

we find, as before,

$$\sqrt{1-k^2}\int_0^{\frac{\pi}{2}}\frac{(A+B\sin^2\theta)\log\delta(k_1,\theta)}{\Delta(\theta)}\,d\theta$$

$$=\int_0^{\frac{\pi}{2}}\frac{\{A+B-(Ak^2+B)\sin^2\theta\}\log\delta(k_2,\theta)}{\Delta(\theta)}\,d\theta$$

$$+\log\sqrt{1-k_1^2}\int_0^{\frac{\pi}{2}}\frac{A+B-(Ak^2+B)\sin^2\theta}{\Delta(\theta)}d\theta$$

$$-\int_0^{\frac{\pi}{2}}\frac{\{A+B-(Ak^2+B)\sin^2\theta\}\log\delta(k,\theta)}{\Delta(\theta)}\,d\theta.$$

Here put

$$A+B=1,\quad Ak^2+B=1-\sqrt{1-k^2},$$

from which

$$A=\frac{1}{\sqrt{1-k^2}},\quad B=-\frac{1-\sqrt{1-k^2}}{\sqrt{1-k^2}}.$$

Hence, transposing, we find

$$\int_0^{\frac{\pi}{2}}\frac{\{1-(1-\sqrt{1-k^2})\sin^2\theta\}\{\log\delta(k_1,\theta)-\log\delta(k_2,\theta)\}}{\Delta(\theta)}\,d\theta$$

$$=\log\sqrt{1-k_1^2}\int_0^{\frac{\pi}{2}}\frac{\{1-(1-\sqrt{1-k^2})\sin^2\theta\}\,d\theta}{\Delta(\theta)}$$

$$-\int_0^{\frac{\pi}{2}}\frac{\{1-(1-\sqrt{1-k^2})\sin^2\theta\}\log\delta(k,\theta)}{\Delta(\theta)}\,d\theta;$$

or, by substitution,

$$\int_0^{\frac{\pi}{2}}\frac{\{1-(1-\sqrt{1-k^2})\sin^2\theta\}\{\log\delta(k_1,\theta)-\log\delta(k_2,\theta)\}}{\Delta(\theta)}\,d\theta$$

$$=\frac{2\log\sqrt{1-k_1^2}-\log\sqrt{1-k^2}}{1+\sqrt{1-k^2}}\,F\left(\lambda,\frac{\pi}{2}\right),$$

where, as before,

$$\lambda^2=\frac{k_1^2(k^2-k_1^2)}{(1-k_1^2)(1+\sqrt{1-k^2})^2}.$$

SECTION II.

In this section I use the following notation :—

$$\Delta(\theta) = \sqrt{(1-k^2\sin^2\theta)(1-k_1^2\sin^2\theta)(1-k_2^2\sin^2\theta)\left(1-\frac{k^2-k_1^2}{1-k_1^2}\sin^2\theta\right)\left(1-\frac{k^2-k_2^2}{1-k_2^2}\sin^2\theta\right)},$$

$$\Delta(\lambda, \phi) = \sqrt{(1-\lambda^2\sin^2\phi)(1-\lambda_1^2\sin^2\phi)(1-\lambda_2^2\sin^2\phi)},$$

where

$$\lambda = \frac{1-\sqrt{1-k^2}}{1+\sqrt{1-k^2}},$$

$$\lambda_1 = \frac{k_1\sqrt{k^2-k_1^2}}{\sqrt{1-k_1^2}\,(1+\sqrt{1-k^2})},$$

$$\lambda_2 = \frac{k_2\sqrt{k^2-k_2^2}}{\sqrt{1-k_2^2}\,(1+\sqrt{1-k^2})}.$$

Let us now consider the integral

$$\int_0^{\frac{\pi}{2}} \frac{(A+B\sin^2\theta+C\sin^4\theta)\,d\theta}{\Delta(\theta)}.$$

Transforming as before we get, after some reduction, the relation

$$\int_0^{\frac{\pi}{2}} \frac{1-2\sin^2\theta+k^2\sin^4\theta}{\Delta(\theta)}\,d\theta = 0.$$

We also find by direct substitution, or otherwise,

$$\frac{(1-\sin^2\phi)\,d\phi}{\Delta(\lambda,\phi)} = (1+\sqrt{1-k^2})\,\frac{\{1-(1+\sqrt{1-k^2})\sin^2\theta\}^2}{\Delta(\theta)}\,d\theta,$$

$$\frac{\sin^2\phi\,d\phi}{\Delta(\lambda,\phi)} = (1+\sqrt{1-k^2})^3\,\frac{(1-\sin^2\theta)\sin^2\theta}{\Delta(\theta)}\,d\delta,$$

where ϕ and θ are connected by the relation

$$\tan\phi = \frac{(1+\sqrt{1-k^2})\tan\theta}{1-\sqrt{1-k^2}\tan^2\theta}.$$

Integrating for θ between 0 and $\frac{\pi}{2}$, and therefore for ϕ between 0 and π, we have three equations to find the integrals

$$\int_0^{\frac{\pi}{2}} \frac{d\theta}{\Delta(\theta)}, \qquad \int_0^{\frac{\pi}{2}} \frac{\sin^2\theta\, d\theta}{\Delta(\theta)}, \quad \text{and} \quad \int_0^{\frac{\pi}{2}} \frac{\sin^4\theta\, d\theta}{\Delta(\theta)},$$

in terms of complete hyper-elliptic integrals with three moduli. We have, namely,

$$\int_0^{\frac{\pi}{2}} \frac{d\theta}{\Delta(\theta)} - 2\int_0^{\frac{\pi}{2}} \frac{\sin^2\theta\, d\theta}{\Delta(\theta)} + k^2\int_0^{\frac{\pi}{2}} \frac{\sin^4\theta\, d\theta}{\Delta(\theta)} = 0,$$

$$\int_0^{\frac{\pi}{2}} \frac{d\theta}{\Delta(\theta)} - 2(1+\sqrt{1-k^2})\int_0^{\frac{\pi}{2}} \frac{\sin^2\theta\, d\theta}{\Delta(\theta)} + (1+\sqrt{1-k^2})^2\int_0^{\frac{\pi}{2}} \frac{\sin^4\theta\, d\theta}{\Delta(\theta)}$$

$$= \frac{2}{1+\sqrt{1-k^2}}\left\{\int_0^{\frac{\pi}{2}} \frac{d\phi}{\Delta(\lambda,\phi)} - \int_0^{\frac{\pi}{2}} \frac{\sin^2\phi\, d\phi}{\Delta(\lambda,\phi)}\right\},$$

$$\int_0^{\frac{\pi}{2}} \frac{\sin^2\theta\, d\theta}{\Delta(\theta)} - \int_0^{\frac{\pi}{2}} \frac{\sin^4\theta\, d\theta}{\Delta(\theta)} = \frac{2}{(1+\sqrt{1-k^2})^3}\int_0^{\frac{\pi}{2}} \frac{\sin^2\phi\, d\phi}{\Delta(\lambda,\phi)}.$$

Solving these equations, and writing

$$L = \int_0^{\frac{\pi}{2}} \frac{d\phi}{\Delta(\lambda,\phi)}, \quad M = \int_0^{\frac{\pi}{2}} \frac{\sin^2\phi\, d\phi}{\Delta(\lambda,\phi)},$$

we find

$$\int_0^{\frac{\pi}{2}} \frac{d\theta}{\Delta(\theta)} = \frac{1}{(1-k^2)(1+\sqrt{1-k^2})}\left\{(2-k^2)L - \frac{k^4 M}{(1+\sqrt{1-k^2})^2}\right\},$$

$$\int_0^{\frac{\pi}{2}} \frac{\sin^2\theta\, d\theta}{\Delta(\theta)} = \frac{1}{(1-k^2)(1+\sqrt{1-k^2})}\left\{L - \frac{k^2 M}{(1+\sqrt{1-k^2})^2}\right\},$$

$$\int_0^{\frac{\pi}{2}} \frac{\sin^4\theta\, d\theta}{\Delta(\theta)} = \frac{1}{(1-k^2)(1+\sqrt{1-k^2})}\left\{L - \frac{(2-k^2)M}{(1+\sqrt{1-k^2})^2}\right\}.$$

If now we transform, as before, the integral

$$\int_0^{\frac{\pi}{2}} \frac{(A + B\sin^2\theta + C\sin^4\theta)\log\delta(k,\theta)}{\Delta(\theta)}\, d\theta,$$

where, as before,

$$\delta(k,\theta) = \sqrt{1-k^2\sin^2\theta}.$$

Putting

$$Ak^2 + B + C = 0,$$

we find

$$2\int_0^{\frac{\pi}{2}} \frac{(B + C - Bk^2\sin^2\theta - Ck^2\sin^4\theta)\log\delta(k,\theta)}{\Delta(\theta)}\, d\theta$$

$$= \log\sqrt{1-k^2}\int_0^{\frac{\pi}{2}} \frac{(B + C - Bk^2\sin^2\theta - Ck^2\sin^4\theta)}{\Delta(\theta)}\, d\theta.$$

Equating, separately, the coefficients of B and C, we have

$$2\int_0^{\frac{\pi}{2}} \frac{(1-k^2\sin^2\theta)\log\delta(k,\theta)}{\Delta(\theta)}\, d\theta = \log\sqrt{1-k^2}\int_0^{\frac{\pi}{2}} \frac{(1-k^2\sin^2\theta)}{\Delta(\theta)}\, d\theta,$$

$$2\int_0^{\frac{\pi}{2}} \frac{(1-k^2\sin^4\theta)\log\delta(k,\theta)}{\Delta(\theta)}\, d\theta = \log\sqrt{1-k^2}\int_0^{\frac{\pi}{2}} \frac{(1-k^2\sin^4\theta)}{\Delta(\theta)}\, d\theta.$$

Hence substituting, in terms of L and M, for the integrals on the right-hand side of these equations, we find the formulæ

$$\int_0^{\frac{\pi}{2}} \frac{(1-k^2\sin^2\theta)\log\delta(k,\theta)}{\Delta(\theta)}\,d\theta = \frac{\log\sqrt{1-k^2}}{1+\sqrt{1-k^2}}\,L,$$

$$\int_0^{\frac{\pi}{2}} \frac{(1-k^2\sin^4\theta)\log\delta(k,\theta)}{\Delta(\theta)}\,d\theta = \frac{\log\sqrt{1-k^2}}{1+\sqrt{1-k^2}}\left\{L+\frac{k^2M}{(1+\sqrt{1-k^2})^2}\right\}.$$

Hence also, as before, we have the additional formulæ

$$\int_0^{\frac{\pi}{2}} \frac{(1-k^2\sin^2\theta)\log\tan\theta}{\Delta(\theta)}\,d\theta = -\frac{\log\sqrt{1-k^2}}{1+\sqrt{1-k^2}}\,L,$$

$$\int_0^{\frac{\pi}{2}} \frac{(1-k^2\sin^4\theta)\log\tan\theta}{\Delta(\theta)}\,d\theta = -\frac{\log\sqrt{1-k^2}}{1+\sqrt{1-k^2}}\left\{L+\frac{k^2M}{(1+\sqrt{1-k^2})^2}\right\},$$

Let now,

$$\delta(k_1,\theta)=\sqrt{1-k_1^2\sin^2\theta},\quad \delta(k_3,\theta)=\sqrt{1-\frac{k^2-k_1^2}{1-k_1^2}\sin^2\theta};$$

then, considering the integral

$$\int_0^{\frac{\pi}{2}} \frac{(A+B\sin^2\theta+C\sin^4\theta)\log\delta(k_1,\theta)}{\Delta(\theta)}\,d\theta,$$

where, as before,

$$Ak^2+B+C=0,$$

we find

$$\int_0^{\frac{\pi}{2}} \frac{\{B+C-Bk^2\sin^2\theta-Ck^2\sin^4\theta\}\,\{\log\delta(k_1,\theta)-\log\delta(k_3,\theta)\}}{\Delta(\theta)}\,d\theta$$

$$=\log\sqrt{1-k_1^2}\int_0^{\frac{\pi}{2}} \frac{(B+C-Bk^2\sin^2\theta-Ck^2\sin^4\theta)}{\Delta(\theta)}\,d\theta$$

$$-\int_0^{\frac{\pi}{2}} \frac{(B+C-Bk^2\sin^2\theta-Ck^2\sin^4\theta)\log\delta(k,\theta)}{\Delta(\theta)}\,d\theta.$$

Hence, substituting in the right-hand side of this equation the previously found values of the integrals in terms of L and M, we get

$$\int_0^{\frac{\pi}{2}} \frac{(1-k^2\sin^2\theta)\{\log\delta(k_1,\theta)-\log\delta(k_3,\theta)\}}{\Delta(\theta)}\,d\theta$$

$$= \frac{2\log\sqrt{1-k_1^2}-\log\sqrt{1-k^2}}{1+\sqrt{1-k^2}}\,L,$$

$$\int_0^{\frac{\pi}{2}} \frac{(1-k^2\sin^4\theta)\{\log\delta(k_1,\theta)-\log\delta(k_3,\theta)\}}{\Delta(\theta)}\,d\theta$$

$$= \frac{2\log\sqrt{1-k_1^2}-\log\sqrt{1-k^2}}{1+\sqrt{1-k^2}}\left\{L+\frac{k^2M}{(1+\sqrt{1-k^2})^2}\right\}.$$

We have, of course, similar formulæ with respect to the modulus k_2.

SECTION III.

In this section I use the following notation:—

$$\Delta(\theta) = \{(1-k^2\sin^2\theta)(1-k_1^2\sin^2\theta)(1-k_2^2\sin^2\theta)(1-k_3^2\sin^2\theta)$$
$$(1-k_4^2\sin^2\theta)(1-k_5^2\sin^2\theta)(1-k_6^2\sin^2\theta)\}^{\frac{1}{2}};$$

in which

$$k_4^2 = \frac{k^2-k_1^2}{1-k_1^2}, \quad k_5^2 = \frac{k^2-k_2^2}{1-k_2^2}, \quad k_6^2 = \frac{k^2-k_3^2}{1-k_3^2},$$

$$X = \int_0^{\frac{\pi}{2}} \frac{d\theta}{\Delta(\theta)}, \qquad Y = \int_0^{\frac{\pi}{2}} \frac{\sin^2\theta\,d\theta}{\Delta(\theta)},$$

$$Z = \int_0^{\frac{\pi}{2}} \frac{\sin^4\theta\,d\theta}{\Delta(\theta)}, \quad W = \int_0^{\frac{\pi}{2}} \frac{\sin^6\theta\,d\theta}{\Delta(\theta)},$$

$$\Delta(\lambda,\theta) = \sqrt{(1-\lambda^2\sin^2\theta)(1-\lambda_1^2\sin^2\theta)(1-\lambda_2^2\sin^2\theta)},$$

where

$$\lambda = \frac{k_1\sqrt{k^2-k_1^2}}{\sqrt{1-k_1^2}\,(1+\sqrt{1-k^2})}, \qquad \lambda_1 = \frac{k_2\sqrt{k^2-k_2^2}}{\sqrt{1-k_2^2}\,(1+\sqrt{1-k^2})},$$

$$\lambda_2 = \frac{k_3\sqrt{k^2-k_3^2}}{\sqrt{1-k_3^2}\,(1+\sqrt{1-k^2})},$$

$$L = \int_0^{\frac{\pi}{2}} \frac{d\theta}{\Delta(\lambda,\theta)}, \qquad M = \int_0^{\frac{\pi}{2}} \frac{\sin^2\theta\, d\theta}{\Delta(\lambda,\theta)}.$$

I propose to express X, Y, Z, W in terms of the complete hyper-elliptic integrals of the first class, L and M, and then to reduce to the same forms other allied definite integrals.

First consider the integral

$$\int_0^{\frac{\pi}{2}} (A + B\sin^2\theta + C\sin^4\theta + D\sin^6\theta)\frac{d\theta}{\Delta(\theta)};$$

transforming, as before, we get

$$\int_0^{\frac{\pi}{2}} (\alpha + \beta\sin^2\theta + \gamma\sin^4\theta + \delta\sin^6\theta)\frac{d\theta}{\Delta(\theta)} = 0,$$

where

$$\alpha = A\,(1-(1-k^2)^{\frac{3}{2}}) + B + C + D,$$

$$\beta = -3Ak^2 - B\,\{1+2k^2+(1-k^2)^{\frac{3}{2}}\} - C\,(2+k^2) - 3D,$$

$$\gamma = 3Ak^4 + Bk^2\,(2+k^2) + C\,\{1+2k^2-(1-k^2)^{\frac{3}{2}}\} + 3D,$$

$$\delta = -Ak^6 - Bk^4 - Ck^2 - D\,\{1+(1-k^2)^{\frac{3}{2}}\},$$

from which we find the relations

$$\alpha\,\{1+(1-k^2)^{\frac{3}{2}}\} + \beta + \gamma + \delta = 0.$$

$$3\alpha\,\{1+\sqrt{1-k^2}\} + \beta\,(2+\sqrt{1-k^2}) + \gamma = 0.$$

We may also prove that α, β, γ, and δ are not connected by any other equations; hence, putting $\alpha = 1$, and, as is usual, writing k' for $\sqrt{1-k^2}$, we find

$$X - 3(1+k')Z + (2+(2+k^2)k')W = 0,$$

$$Y - (2+k')Z + (1+k')W = 0.$$

Now, it may be proved by direct substitution or otherwise,

$$\frac{(1-\sin^2\phi)\,d\phi}{\Delta(\lambda,\phi)} = (1+k')\{1-(1+k')\sin^2\theta\}^2\{1-(1-k')\sin^2\theta\}\frac{d\theta}{\Delta(\theta)},$$

$$\frac{\sin^2\phi\,d\phi}{\Delta(\lambda,\phi)} = (1+k')^3\sin^2\theta(1-\sin^2\theta)\{1-(1-k')\sin^2\theta\}\frac{d\theta}{\Delta(\theta)},$$

where

$$\tan\phi = \frac{(1+k')\sin\theta\cos\theta}{1-(1+k')\sin^2\theta}.$$

Hence, integrating for θ between 0 and $\frac{\pi}{2}$, we get

$$X - (3+k')Y + (2+k^2+2k')Z - k^2(1+k')W = \frac{2(L-M)}{(1+k')},$$

$$Y - (2-k')Z + (1-k')W = \frac{2M}{(1+k')^3}.$$

Hence, solving the four equations for X, Y, Z, W, we find

$$X = \frac{1}{k'^2(k'-k^2)}\left\{(2+k^2-k'-k'k^2)L - (1-k')(2+k^2-k')M\right\},$$

$$Y = \frac{1}{k'^2(k'-k^2)(1+k')}\left\{(1+k^2)L - 2k^2M\right\},$$

$$Z = \frac{1}{k'^2(k'-k^2)(1+k')}\left\{L - \frac{k^2+k'}{1+k'}M\right\},$$

$$W = \frac{1}{k'(k'-k^2)(1+k')}\left\{\quad -\frac{1+k'+k'^2}{1+k'}M\right\}.$$

Consider now the integral

$$\int_0^{\frac{\pi}{2}} \{A + B\sin^2\theta + C\sin^4\theta + D\sin^6\theta\} \log\delta(k,\theta)\frac{d\theta}{\Delta(\theta)},$$

where, as before,

$$\delta(k,\theta) = \sqrt{1-k^2\sin^2\theta}.$$

If we make

$$Ak'^3 = A + B + C + D,$$

$$Bk'^3 = -3Ak^2 - B(1+2k^2) - C(2+k^2) - 3D,$$

we find, without difficulty,

$$2\int_0^{\frac{\pi}{2}} \{A + B\sin^2\theta + C\sin^4\theta + D\sin^6\theta\} \log\delta(k,\theta)\frac{d\theta}{\Delta(\theta)}$$

$$= \log k' \int_0^{\frac{\pi}{2}} \{A + B\sin^2\theta + C\sin^4\theta + D\sin^6\theta\} \frac{d\theta}{\Delta(\theta)}.$$

Hence, equating on each side the coefficients of A and B, we have

$$2\int_0^{\frac{\pi}{2}} \{1 - 3(1-k')\sin^4\theta + (1-k')^2(2+k')\sin^6\theta\} \log\delta(k,\theta)\frac{d\theta}{\Delta(\theta)}$$

$$= \log k' \{X - 3(1-k')Z + (1-k')^2(2+k')W\}$$

$$2\int_0^{\frac{\pi}{2}} \{\sin^2\theta - (2-k')\sin^4\theta + (1-k')\sin^6\theta\} \log\delta(k,\theta)\frac{d\theta}{\Delta(\theta)}$$

$$= \log k' \{Y - (2-k')Z + (1-k')W\}.$$

Hence, putting in the previously found values of X, Y, Z, and W, we find

$$\int_0^{\frac{\pi}{2}} \{1 - (1-k')(2+k')\sin^2\theta + (1-k')^2(1+k')\sin^4\theta\} \log\delta(k,\theta)\frac{d\theta}{\Delta(\theta)}$$

$$= \frac{\log k'}{(1+k')} L,$$

$$\int_0^{\frac{\pi}{2}} \{\sin^2\theta - (2-k')\sin^4\theta + (1-k')\sin^6\theta\} \log\delta(k,\theta)\frac{d\theta}{\Delta(\theta)} = \frac{\log k'}{(1+k')^3} M.$$

In a precisely similar manner we find the formulæ

$$\int_0^{\frac{\pi}{2}} \{1-(1-k')(2+k')\sin^2\theta + (1-k')^2(1+k')\sin^4\theta\} \log\tan\theta \cdot \frac{d\theta}{\Delta(\theta)} = -\frac{\log k'}{1+k'} L,$$

$$\int_0^{\frac{\pi}{2}} \{\sin^2\theta - (2-k')\sin^4\theta + (1-k')\sin^6\theta\} \log\tan\theta \cdot \frac{d\theta}{\Delta(\theta)} = -\frac{\log k'}{(1+k')^3} M.$$

Finally, considering the integral

$$\int_0^{\frac{\pi}{2}} \{A + B\sin^2\theta + C\sin^4\theta + D\sin^6\theta\} \log\delta(k_1,\theta)\frac{d\theta}{\Delta(\theta)},$$

where, as before,

$$\delta(k_1,\theta) = \sqrt{1-k_1^2\sin^2\theta},$$

and

$$Ak'^3 = A + B + C + D,$$

$$Bk'^3 = -3Ak^2 - B(1+2k^2) - C(2+k^2) - 3D,$$

we find the formulæ

$$\int_0^{\frac{\pi}{2}} \{1-(1-k')(2+k')\sin^2\theta + (1-k')^2(1+k')\sin^4\theta\} \{\log\delta(k_1,\theta) - \log\delta(k_4,\theta)\}\frac{d\theta}{\Delta(\theta)} = \frac{2\log\sqrt{1-k_1^2} - \log k'}{1+k'} L,$$

$$\int_0^{\frac{\pi}{2}} \{\sin^2\theta - (2-k')\sin^4\theta + (1-k')\sin^6\theta\} \{\log\delta(k_1,\theta) - \log\delta(k_4,\theta)\}\frac{d\theta}{\Delta(\theta)} = \frac{2\log\sqrt{1-k_1^2} - \log k'}{(1+k')^3} \cdot M,$$

with, of course, similar formulæ with respect to the other moduli.

XII.—*On the Embryology of the Mammalian Muscular System.* No. I.—*The Short Muscles of the Human Hand.* By Bertram C. A. Windle, A. B., M. B., B. Ch., and Senior Moderator in Natural Science, University of Dublin; Pathologist to the General Hospital, Birmingham; late Demonstrator of Anatomy and Histology, Royal College of Surgeons, Ireland. [With Plates III. and IV.]

[Read, June 26, 1882.]

In a former communication, which I had the honour of laying before the Royal Irish Academy in June, 1881,* I gave a short account of the appearances seen in transverse sections through the manus and pes of the fœtal puppy.

In that Paper I stated that I hoped soon to be in a position to lay before the Academy a report of my investigations on the musculature of the human manus. Two obstacles have prevented an earlier fulfilment of that promise, namely, the difficulty of finding time for continuous microscopical work in the midst of other avocations, and the even still greater difficulty of obtaining material suitable for an investigation such as this; and I wish here to take the opportunity of thanking Dr. Macalister, Professor of Anatomy in the University of Dublin, Dr. Purser, Professor of the Institutes of Medicine in the same University, and Dr. William C. Neville, Assistant-Master of the Coombe Lying-in Hospital, Dublin, for supplying me with fœtuses of various sizes, without which I should have

* "Preliminary Report on the Embryology of the Mammalian Muscular System."—*Proc.* Royal Irish Academy, 2nd Series, Vol. III. (Science), page 501 (No. 7, Dec., 1881).

been unable to have carried out the researches which I have embodied in this Paper.

I must also express my obligations, for much kind assistance, to Dr. Macalister, and Dr. Cunningham, Professor of Anatomy in the Royal College of Surgeons, Ireland, the former of whom suggested this undertaking to me, and gave me much valuable advice and help in pursuing it; and the latter of whom most kindly looked over with me the sections described, and in other ways aided me most materially in the preparation of this Paper.

The development of the muscular system of the hand has, up to the present, received but a small amount of attention. So far as I am aware, the sole published researches on the subject will be found in a foot-note in a Paper by Ruge, of Heidelberg, on the Development of the Muscular System of the Human Foot.* This Paper is put forward as a slight effort to supply some information on this division of the Embryology of the Mammalian Muscular System.

I have examined, with the aid of the microscope, sections taken transversely through the hands of fœtuses of the following sizes, 2·4 cms., 5 cms., 7 cms., 12 cms. The measurements are taken in every case from the vertex to the buttocks, and this is indicated throughout the Paper by the letters H. B. M. (*i. e.* head and buttocks measurement). This method of arranging them, which is used by Ruge in his Paper just mentioned, appears to me to be far more satisfactory than one founded on the supposed ages of the fœtuses, as such a classification is open to too many sources of error.

I have tried a number of staining fluids, but the two which have given me the best results are methyline blue and picrocarmine: the former has brought out the points in some of the smaller sections in a way which leaves nothing to be desired, whilst the capabilities of the latter are too well known to require more than a passing recognition.

The method on which I have proceeded throughout my Paper is as follows: I have chosen representative sections taken at different points

* Morphologische Jahrbuch, Bd. iv., Suppl. Entwicklungs—Vorgänge an der Muskulatur des menschlichen Fusses, von Georg Ruge, Assistant an der Anatom. Anstalt zu Heidelberg—p. 125.

through the hands, and have described the objects visible in them. I have next devoted some pages to a comparison of each group of muscles as it appears in the various sections, and incidentally I have endeavoured to draw attention to some other points of interest which have arisen throughout the Paper, and which need not be more particularly specified here. I have figured (Plates III. and IV.) all the sections described. These illustrations, not having been executed with the aid of a camera, cannot be considered as drawn to scale, but I have endeavoured to represent in a semi-diagrammatic manner the appearances seen so as to elucidate the text.

Having said thus much by way of introduction, I proceed without further preface to the description of the various sections:—

FŒTUS OF 2·4 cms. H. B. M.

I.—Section through Bases of Metacarpal Bones.

(Plate III., Fig. 1.)

A.—BONES.

The metacarpal of the pollex is somewhat egg-shaped, with dorso-radially-directed apex, the base being flattened and directed towards the centre of the palm of the hand. The index is wedge-shaped, with the apex directed towards the palmar aspect of the hand. The medius is in form like a shield. The annularis is ellipsoidal, whilst the minimus has a lozenge-shaped outline with rounded corners. All the bones are in close proximity to one another—in fact their periosteal margins, which are very broad, are in contact.

B.—MUSCLES.

a. Thenar Region.

On examining this portion of the section with a low power, it at first appeared to me that there was but one muscular bundle in this group. On making a more careful study, however, with a higher power, I found that which I had previously taken for one fasciculus was really two which

had been mixed together, and confused with some connective tissue by the passage through their substance of the razor in making the section. I have, therefore, not attempted in the figure to map out their outlines, and have only indicated the position of the mass of fibres which I believe to represent flexor brevis and abductor pollicis.

β. Hypothenar Region.

1. *Abductor minimi digiti.*—Situated superficially to the next muscle, which it slightly exceeds in bulk.

2. *Opponens minimi digiti.*—Lies deeper than the others, and its fibres are lost on the palmar surface of the minimus, from which they pass almost transversely to a point situated in the palm of the hand, slightly to the ulnar side of the centre of the index.

3. *Flexor brevis minimi digiti.*—A small muscle in excessively close contact with the last—so much so in fact that the two are almost inseparable. Its radial extremity extends to the angle at the radial side of the lozenge-shaped pollex. From this point its fibres extend to the angle between the radial extremities of the opponens and abductor.

II.—Section passing approximately through the Centre of the Metacarpal Bones.

(Plate III., Fig. 2.)

A.—BONES.

All the bones in this section are more or less circular in outline, departing only from this shape on their palmar surfaces, which are more pointed than are their dorsal. This is best marked in the case of the pollex, which accordingly has somewhat the appearance of a wedge with very much rounded outlines. The minimus is perhaps slightly larger than its fellows, but there is but little difference in bulk between any of them at this plane. The greatest space intervening between any pair of bones is that between the pollex and index, which is very nearly double thatwhich exists between any other two bones. The other interspaces are very nearly of the same size.

B.—MUSCLES.

a. Thenar Region.

In order to explain the terminology of the muscles of this region which I propose adopting throughout the remainder of this Paper, it will be necessary for me to pause here for a short time, and turn aside from the description of the appearances seen in this hand to the consideration of the nomenclature of the thumb muscles.

In a lengthy and elaborate monograph on the Anatomy of *Hylobates leuciscus* by Bischoff,* and also in a Paper on the Relation of Nerve-supply to Muscle Homology by Cunningham,† attention has been drawn to the false views held as to the nomenclature of the muscles of the thumb.

The latter author says:‡ ". . . the adductor pollicis is the serial homologue of the transversus pedis, and the deep head of the flexor brevis pollicis, the serial homologue of the adductor hallucis. But where is the true inner head of the flexor brevis pollicis? This is a muscular slip, which is almost invariably present; but, owing to the great development of the adductors, it has been thrust deeply into the palm. It is the interosseus primus volaris of Henle."

Adopting the views put forward in the two memoirs just mentioned, we must endeavour to remodel the nomenclature of the short muscles of the thumb. I propose to use throughout this Paper the following terminology:—

Adductor transversus substituted for adductor pollicis.

Adductor obliquus substituted for deep head of flexor brevis pollicis.

Deep head of flexor brevis pollicis substituted for interosseus primus volaris of Henle.

The superficial head of flexor brevis, opponens, and adductor pollicis do not require to be re-named.

* Beiträge zur Anatomie des Hylobates leuciscus und zu einer vergleichenden Anatomie der Muskeln der Affen und des Menschen. Von Th. L. W. Bischoff. München, 1870.

† The relation of Nerve-supply to Muscle-Homology, by D. J. Cunningham, M.D. *Journal of Anatomy and Physiology*, vol. xvi.

‡ *Op. supra cit.*, pp. 8, 9.

After this needful digression we may return to the consideration of the thumb-muscles in this particular section.

1. *Adductor transversus et obliquus.*—This is the first muscle which catches the eye on looking at this section. It is triangular in shape, with its base directed towards the pollex. From this its fibres extend transversely across the palm of the hand to a point situated below the inner margin of the index. At this stage and plane there is no evidence of a division into two muscular bundles.

2. *Flexor brevis pollicis, caput profundum.*—Lies on the dorsal aspect of the apex of the wedge-shaped deep portion of the pollex.

3. *Flexor brevis pollicis, caput superficiale.*—Placed on the ulnar side of the bone and on the plantar aspect of the wedge just mentioned.

4. *Opponens pollicis.*—Placed superficial to the last, from which it is evidently segmenting off.

5. *Abductor pollicis.*—Situated directly on the palmar of the pollex.

β. Hypothenar Region.

In this part of the section we find two muscular bundles:

1. A fasciculus situated on the ulno-palmar aspect of the minimus. This consists in all probability of fibres belonging to the flexor brevis and opponens minimi digiti, but at this plane there is no evidence of a division into two muscles.

2. *Abductor minimi digiti.*—A large bundle of transversely-divided fibres, which has been displaced forward by the razor.

γ. Interossei.

A.—Dorsal.

1. Occupies a considerable portion of the first interspace, and is applied to the greater part of the radial aspect of the index. Its upper edge is nearly on a level with the dorsal surface of that bone.

2. Lies on the radial aspect of the medius. Its lower extremity lies on the palmar surface, whilst its apex extends about half way up the side of the bone towards the dorsum of the hand.

3. Is situated on the ulnar side of the same bone, round which it curves, its base occupying the ulnar half of the palmar surface of the bone, whilst its apex ascends in the third interspace to a point situated dorsal to the centre of the former bone.

4. Placed on the ulnar side of the annularis, ascends towards the dorsum of the hand to a point situated about the middle of that bone. It extends downwards into the palm considerably below the bone.

B.—Palmar.

1. Lies on the palmar surface chiefly, but for a small extent also on the ulnar aspect of the index.

2. Situated on the radial side of the annularis. Its most dorsal fibres do not encroach upon the interspace. It curves round the bone, so that its palmar fibres cover about one-half of the palmar surface of the metacarpal.

3. Extends about half way up radial side of minimus, and curves round its lower border, but not so much as the last-mentioned muscle does round its metacarpal.

FŒTUS OF 5 cms. H. B. M.

I.—Section through Second Row of Carpal Bones.

(Plate III., Fig. 3.)

A.—BONES.

This section (Plate III., Fig. 3), passes through the unciform, which will easily be recognized by its hook-like process, the os magnum, trapezoid, and trapezium. They are all very closely applied to one another. From the apex of the hook-like process of the unciform bone springs the anterior annular ligament, which, having embraced the flexor tendons which run between it and the bony carpal arch, is attached partly to the trapezium, but also by a slip to the trapezoid.

B.—MUSCLES.

α. Thenar Region.

Lying partly on the trapezium, but to a very considerable extent also on the annular ligament, to which some of them seem to be attached, are a number of transversely-running fibres, forming a bundle of considerable size. There is no obvious division in it, and probably the fibres all, or nearly all, belong to the abductor pollicis.

β. Hypothenar Region.

A large triangular bundle of fibres is situated on the ulnar side and palmar aspect. These fibres are in close contact with the unciform, but do not extend sufficiently far towards the centre of the manus to be in relation with the annular ligament. The mass presents but little trace of differentiation, and probably consists of abductor and flexor brevis minimi digiti, from which opponens has not yet been segmented.

C.—TENDONS.

Besides the tendons of the long flexors already alluded to, a faint line in the most superficial part of the centre of the palmar aspect indicates the position of the tendon of the palmaris longus. The tendon of the flexor carpi radialis lies in the groove in the trapezium.

II.—Section through Bases of Metacarpal Bones.

(Plate III., Fig. 4.)

A.—BONES.

The pollex and index are of a somewhat wedge-shaped figure, with palmar-directed apices: whilst, however, the dorsal aspect of the latter is rounded, that of the former is gable-shaped.

The medius resembles roughly a shield. Its broadest portion is also directed dorsalwards.

The annularis is nearly round, the side next the medius being somewhat flattened. The minimus is also nearly circular. The pollex, index,

and medius are the largest, and are of nearly equal size. The remaining three decrease in size from the medius to the minimus. All the bones are in tolerably close contiguity to one another, the three central ones especially so. The greatest space which intervenes between any two is that between annularis and minimus; the next, that between pollex and index. Index, medius, and annularis, touch one another by their broad periosteal margins.

B.—MUSCLES.

α. Thenar Region.

1. *Abductor pollicis.*—Situated most superficially on the radial side and palmar aspect of pollex. Towards the ulnar side of the muscle its fibres are in very close relation to those of the next.

2. *Opponens pollicis.*—Situated beneath the last-mentioned muscle, but does not extend so far towards the radial side of the pollex as it does.

3. *Flexor brevis pollicis.*—In contact with the palmar surface of the pollex, and passes up as far as its radial ridge. Its fibres can only be distinguished from those of the last by their direction on section, and the two together form a large muscle of somewhat triangular shape.

4. *Adductor.*—A number of transversely-running fibres situated upon so much of the ulnar aspect of the pollex as extends into the palm of the hand. From thence they may be seen passing as far towards the centre of the palm as the medius. With regard to the question as to whether this muscle should be considered the transversus, or obliquus, or both, I am inclined to take the last view for the following reasons:—The close apposition of some of its fibres to the tendon of the flexor longus pollicis is an argument in favour of their belonging to the obliquus, whilst the transverse course which the greater part of the muscle takes towards the centre of the palm points to a portion of it being transversus.

β. Hypothenar Region.

1. *Abductor minimi digiti.*—The greater portion of this muscle is situated directly on the ulnar aspect of the minimus: a few fibres pass down, however, towards the palm.

2. *Flexor brevis minimi digiti.*—Situated on the palmar surface of the minimus, from which it is separated by the next muscle.

3. *Opponens minimi digiti*—which is situated in close connexion with the ulnar and palmar aspects of the minimus, which it separates from the last two muscles. There is at this stage and plane a distinct separation between this muscle and the one described just before it.

γ. Interossei.

The two belonging to the fourth interspace are visible in this section, viz.:—

Fourth Dorsal—which occupies the ulnar third of the palmar surface of the annularis. A few of its fibres encroach slightly upon the ulnar side of that bone.

Third Palmar.—Larger in size than the last, and nearly circular in shape; lies on the palmar-directed narrower end of the ovoid-shaped minimus. Its fibres do not encroach at all upon the interspace.

III.—Section through approximate Centre of Metacarpal Bones.

(Plate III., Fig. 5.)

A.—BONES.

The pollex presents a somewhat heart-shaped appearance, the apex, which is radio-dorsally directed, being, however, blunter than that of the figure conventionally understood to represent that organ. The remaining metacarpal bones are of a more or less rounded figure, the annularis being a nearly perfect circle, whilst the minimus is more egg-shaped, with its narrower end directed towards the palmar aspect of the hand. The pollex is the largest; the index and medius come next, being nearly equal in size; the minimus is next, whilst the annularis is the smallest. There is a very wide space intervening between the pollex and index—by far the widest separating any two of the bones in this section: it is about equal in breadth to the diameter of the index. The next widest space intervenes between the annularis and minimus, but this is not much more than half

that separating the pair of bones just alluded to. The space between the medius and annularis is a trifle smaller than that between the annularis and minimus, whilst that between the index and medius is the smallest of all.

B.—MUSCLES.

α. Thenar Region.

This portion of the section is occupied by a large mass of muscular fibres, which can only be differentiated with considerable difficulty, owing partly to the absence of the tendon of the flexor longus pollicis, and partly to the fact that all the parts are in extremely close relation to one another. It can be made out, however, to consist of five, more or less, distinct portions, viz.:—

1. *Abductor pollicis.*—Very thin, only the distal extremity being present: situated at the radio-palmar angle of the bone, from which it is separated by the next two muscles.

2. *Opponens pollicis.*—Situated between this last and the next muscle.

3. *Flexor brevis pollicis.*—More or less conjoined with the last at its radial, but quite free from it at its ulnar, end.

4. *Adductor obliquus.*—Fused with transversus at radial end, but distinct from it at its ulnar, owing to its fibres not passing so far across the hand, and ending tendinously.

5. *Adductor transversus.*—Passes from the ulnar surface of the pollex to the palmar surface of the medius.

β. Hypothenar Region.

1. *Abductor minimi digiti.*—This muscle is situated on the palmar aspect and towards the ulnar side of the minimus. There is not nearly so wide an interval separating it from the next muscle to be mentioned as existed in the last-described section.

2. *Flexor brevis minimi digiti.*—A rounded mass lying on the radial part of the palmar surface of the minimus.

3. *Opponens minimi digiti.*—A somewhat quadrilateral mass lying on the ulnar aspect of the same bone.

γ. Interossei.

A.—Dorsal.

1. Occupies the entire of the first interspace, which is, as has already been mentioned, the widest existing between any two bones in this section. Its fibres occupy the entire of the radial side of the index and also a considerable portion of its palmar aspect, but they do not encroach at all upon the dorsum of the bone.

2. Lies upon the dorsal aspect, for the most part, but also upon the ulnar side for a part of its extent of the index.

3. Lies in the third interspace, which it almost entirely fills. It rises towards the dorsum of the hand to a point slightly above the middle of the medius. It, however, considerably overtops the annularis—a fact explained partly by the considerably smaller size of that bone, and partly by its being placed on a plane nearer the palmar surface of the hand.

4. Is placed on the ulnar side, and partly on the palmar aspect of the annularis. It only extends to a point midway on the ulnar side of the bone in the direction of the dorsum of the hand. It will be noticed that the second dorsal interosseus occupies the most dorsal position of any of the muscles just described, whilst the fourth is situated more towards the palmar aspect than any of the others.

B.—Palmar.

1. Occupies the lower part of the second interspace, and is applied to the palmar aspect and ulnar side of the second bone.

2. Lies almost entirely on the palmar surface of the annularis, but more towards its radial than its ulnar side. It does not encroach upon the interspace between the medius and annularis.

3. Occupies the lower part of the fourth interspace, lying on the radial side of the minimus. It does not reach so far towards the dorsum as the dorsal interosseus, occupying the same interspace, but projects down into the palm.

Fœtus of 7 cms. H. B. M.

I.—Section through Bases of Metacarpals.

(Plate IV., Fig. 1.)

A.—BONES.

The pollex, index, and medius all possess a figure ranging in shape from that of a wedge to that of a shield, the medius most resembling the latter figure. Their apices are directed towards the palmar surface of the hand; the annularis is also somewhat shield-shaped, but has a more rounded outline than the medius. The minimus is ovoid: it is also the smallest, the annularis coming next, whilst the other three are more or less of the same shape. The first four bones are in very close contiguity to one another: in the cases of the pollex and index, and the medius and annularis, they are in direct apposition. There is a slight interval between index and medius. A larger interspace exists between annularis and minimus, which corresponds approximately to the breadth of the latter bone.

B.—MUSCLES.

a. Thenar Region.

1. *Adductor.*—A number of fibres placed very transversely and situated deep in the palm of the hand, which pass from the ulnar side of the apex of the pollex to the apex of the medius. From this point a few fibres appear to be carried on to the palmar surface of the annularis.

2 and 3. Sickle-shaped muscle, beginning by a pointed extremity at the radial border of the pollex, and extending from this over the entire palmar surface of the bone, and even beyond this for a certain distance into the palm, where it ends in a rounded extremity. This muscle undoubtedly contains elements of the flexor brevis and opponens; but the only evidence of its double constitution is a tendency to an oblique cleavage, separating the densely-aggregated outer fibres from the more loosely arranged inner fibres. The former then would seem to be equivalent to the flexor brevis, whilst the latter represent the opponens.

4. *Abductor pollicis.*—This lies superficial to the two last muscles. Its fibres, which are cut transversely, do not extend quite so far towards the centre of the palm as do those of the flexor brevis, nor do the upper fibres approach so near to the dorsum of the hand as those of the opponens. This muscle, however, is much larger than either of the other two, but is not so large as both combined.

β. Hypothenar Region.

1. *Abductor minimi digiti.*—This lies superficial to the other two muscles in connexion with this metacarpal. It is placed on the palmar surface of the bone, from which it is separated by the next muscle. A muscular mass, with distinct evidence of division in it, the fibres running in two different directions: this represents two muscles, viz. :—

2. *Flexor brevis minimi digiti*—whose fibres cover about one-half of the palmar aspect of the minimus, and from thence extend towards the centre of the palm, to a point situated below the middle of the fourth interspace.

3. *Opponens minimi digiti*—which is placed deepest of the three muscles. Its fibres are attached to the inner half of the palmar surface of the minimus, and extend thence about as far towards the centre of the palm as do those of the last-mentioned muscle. The largest muscle of the three is the abductor.

γ. Interossei.

The proximal extremities of the last dorsal and palmar interossei occupy the fourth interspace, which is the only interspace, indeed, in which there is any room for muscles to lie.

Fourth Dorsal.—Occupies the whole of the interspace lying on the radial and dorsal surface of the minimus. It extends dorsal-wards to a point beyond the level of the dorsal surface of the bones.

Third Palmar.—Occupies the palmar and radial aspects of the minimus. Its fibres are cut somewhat obliquely.

δ. Superficial Muscle.

Palmaris brevis.—Situated on the radial face of the palmar surface of the abductor minimi digiti, from which, however, it is separated by a considerable interval, being situated in quite a subcutaneous position.

II.—Section approximately through the Centre of the Metacarpals.

(Plate IV., Fig. 2.)

A.—BONES.

Pollex, index, and medius, are all more or less wedge-shaped, the first having a sharp palmar-directed apex and a rounded dorsum. The second has its radial side much flattened, whilst its ulnar is notched. The third is rather shield- than wedge-shaped.

Annularis and minimus are quadrilateral, each having a depression on the sides facing each other, whilst the latter also has a depression on its palmar side.

The annularis is the largest bone, minimus next, medius third, index fourth, and pollex the least in size.

By far the largest interspace is that between pollex and index, which is fully double the size of any of the others. Of the rest, that between medius and index and medius and annularis is about equal, whilst that between annularis and minimus is the smallest.

B.—MUSCLES.

a. Thenar Region.

1. *Abductor pollicis.*—This muscle lies most superficially, and only its distal end is seen.

2. *Opponens pollicis.*—This muscle, which lies on the palmar surface of the pollex, is very closely combined with the next.

3. *Flexor brevis pollicis, caput superficiale*—which separates its central half from the bone. From this muscle a number of fibres can be seen passing between the tendon of the flexor longus pollicis and the pollex, to join the next muscle.

4. *Adductor obliquus*—which is situated under cover of the adductor transversus, and just below the next.

5. *Flexor brevis pollicis, caput profundum*—is placed deep in the palm of the hand; also between the base of the adductor and the pollex. Its fibres are cut transversely.

6. *Adductor transversus.*—Somewhat triangular in shape, with its base directed towards the pollex, but separated from it by the two muscles just mentioned. From thence its fibres extend to the palmar surface of the medius, to which they become attached. On their way to this point some of them come into very close contact with the palmar surface of the index, and appear to have an attachment to it.

β. Hypothenar Region.

On the ulnar side of the minimus there is situated a large-sized nodule of cartilage attached to the cartilage, which subsequently becomes the bone, by firm ligaments: it has all the appearance of one of the cartilages which subsequently ossify into sesamoid bones. If such it be, however, I must confess myself quite at a loss to account for its position here. To the palmar portion of this cartilage is attached the only muscular bundle which is visible in this part of the section. This represents either the flexor brevis or opponens, or both; probably the last, though it is impossible to say with certainty.

γ. Interossei.

A.—Dorsal.

1. Occupies the greater part of the first interspace, and is applied against the radial side of the index, the whole of which it covers. Its dorsal aspect is on a level with the dorsum of the bone just mentioned.

2. Covers the entire of the radial side of the medius, encroaching very slightly also upon its palmar surface. Its dorsal surface is on a level with that of the previous muscle.

3. Is wedge-shaped with palmar-directed apex, and covers the upper half of the ulnar aspect of the medius. Its dorsal surface lies on a lower plane than those of the first two muscles.

4. Is in very close apposition to the palmar interosseus of the same space. It is much smaller than any of the other dorsal interossei, approximately circular in shape, and only extends towards the dorsum of the hand slightly above the centre of the interspace which it occupies.

B.—Palmar.

1. Occupies the radial half of the second interspace, covering all that side of the index, and a small part of its palmar aspect. It is wedge-shaped, with dorsally-directed apex. It is about the same size as the dorsal interosseus of the same space.

2. Is also wedge-shaped, with dorsally-directed apex, and of about the same size as its fellow in the interspace. It lies in close apposition to the radial side of the annularis.

3. Occupies a position in the fourth interspace, more towards the palm of the hand than the corresponding dorsal muscle, with which it is in very close relation, and which it somewhat exceeds in size.

FŒTUS OF 12 cms. H. B. M.

I.—Section through Bases of Metacarpal Bones.

(Plate IV., Fig. 3.)

A.—BONES.

Pollex and index are of a wedge shape; the first, however, having much more rounded outlines than the second, which is nearly a perfect triangle. Medius is of a shield-like form. I may remark that the shape of this bone throughout is so extremely characteristic that it would be quite possible to recognize it from any of the others, were they all placed

separately on the slide. Annularis is irregularly quadrilateral. In all these cases the broadest portion of the bone is placed towards the dorsum of the hand. Minimus is oval in shape, its long axis being very nearly in the direction of the breadth of the hand.

The bones diminish very gradually in size from pollex, which is the largest, to minimus.

With the exception of annularis and minimus, which are separated by an interspace broad enough to admit two interossei, the bones are in close apposition to one another.

B.—MUSCLES.

a. Thenar Region.

1. *Abductor pollicis.*—Is placed most superficially, and on the palmar surface, and rather towards the ulnar side of the pollex, from which it is separated by the opponens and flexor brevis.

2. *Opponens pollicis.*—This is a triangular muscle, with its base placed towards the pollex, the flexor brevis intervening. Its radial side is subcutaneous, but its ulnar surface is covered by the last-mentioned muscle.

3. *Flexor brevis pollicis.*—The largest of the four muscles connected with the pollex in this section. Its fibres cover the whole of the palmar, and more than half of the ulnar surface of the bone; and from this extensive relation they taper to a point, and extend towards the centre of the hand to a spot situated under the index, where it is seen to be attached to the distal edge of the annular ligament.

4. *Adductor.*—The fibres of this muscular mass extend from that part of the ulnar surface of the pollex, which is neither covered by the last-mentioned muscle nor in contact with the next bone, to the apex of the medius. This muscle is, at this part of the hand, thin, flat, and separated from the remainder by the tendons of the long flexors of the fingers and of the thumb, the latter of which lies in a separate sheath in close contiguity to the pollex. This muscle contains, in my opinion, fibres belonging to both transversus and obliquus.

β. Hypothenar Region.

1. *Abductor minimi digiti.*—A large kidney-shaped muscle, lies with its concave surface facing the minimus, the ulnar side of which it completely covers with its upper half, the remaining portion extending down to the palm of the hand.

2 and 3. *Flexor brevis and opponens.*—A somewhat quadrilateral mass of muscular fibres covers the palmar surface of the minimus with one side. The second is in close relation with the lower half of the abductor. The third is subcutaneous, and the fourth extends towards the centre of the hand to a point below the ulnar margin of the annularis. This obviously represents the two muscles above mentioned, but there is no appearance of demarcation between them.

γ. Interossei.

As was mentioned before, the interspace between the annularis and minimus is the only one sufficiently wide to admit interossei. In it there are two, viz :—

Fourth Dorsal.—Which embraces the ulnar side of the annularis, encroaching for a short distance on both the dorsal and palmar aspects of the bone.

Third Palmar.—Which, somewhat larger than its fellow, covers the whole of the radial side, and a part of the palmar and dorsal surfaces of the minimus.

II.—Section through Approximate Centre of Metacarpus.

(Plate IV., Fig. 4.)

A.—BONES.

The pollex, index, and annularis are all of a nearly circular outline. Medius and minimus are wedge-shaped, with their apices directed towards the palmar surface of the hand. It may be worth mentioning, whilst speaking of the bones, that this is the first section in this series of hands in

which ossification has been noticed in them. In it all the bones occur as osseous rings, save minimus, which is cartilaginous.

Pollex and minimus are about equal in size, and larger than the other bones: medius and annularis come next, whilst index is the smallest.

The largest interspace is that between pollex and index, which is about twice the breadth of either of these bones. The other interspaces are nearly equal in size; that between the medius and annularis being, perhaps, the smallest.

B.—MUSCLES.

a. Thenar Region.

1. *Abductor pollicis.*—Only the distal fibres of this muscle are visible, cut transversely, and placed at the radial end of the opponens, which, together with flexor brevis (superficial head), separate it from the pollex.

2. *Opponens pollicis.*—A triangular muscle, with its base directed towards the radial margin of the hand, and its apex extending towards the centre of the hand.

3. *Flexor brevis pollicis* (*caput superficiale*).—The fibres of this muscle cover the greater part of the palmar and about half the ulnar aspects of the pollex, and thence extend towards the centre of the palm, for the same distance as do those of the previous muscle.

4. *Flexor brevis pollicis* (*caput profundum*).—A triangular muscle, with its base covering the dorsal half of the ulnar surface of the pollex; its dorsal surface in contact with the first dorsal interosseous, and its palmar with the next muscle to be described.

5. *Adductor obliquus.*—A somewhat kidney-shaped muscle, situated between the base of the abductor transversus and the angle formed between the two heads of the flexor brevis pollicis.

6. *Adductor transversus*—Is a somewhat irregularly-triangular muscle. Its base is directed towards the pollex, from which it is separated by the deep head of the flexor brevis, and the adductor obliquus. From this point its fibres extend upwards to the palmar surface of the index, and thence transversely to the same aspect of the medius.

β. Hypothenar Region.

1 and 2. A large bundle of fibres covering about half the ulnar surface of the minimus, and lying also on its palmar surface, from both of which it is separated by the next muscle.

Its ulnar fibres are cut transversely and its radial obliquely, but there is no other evidence of division into two muscles. The former represents the abductor, the latter the flexor brevis.

3. *Opponens minimi digiti.*—A thin, flat fasciculus of muscular fibres, covering the palmar and half the ulnar surface of the minimus.

γ. Interossei.

A.—Dorsal.

1. This, which is by far the largest of the interossei, occupies the entire of the broad interspace between the pollex and index, save that portion of it which is encroached upon by the deep head of the flexor brevis pollicis.

2. A muscle triangular in shape, as is its fellow in the space. Its base is directed towards the dorsum of the hand; one side lies in close proximity to the radial side of the medius, whilst the remaining one is related to the first palmar interosseus.

3. Occupies rather more than the radial half of the third interspace, and is applied against the ulnar surface of the medius. It entirely fills the upper part of the space, and its fibres therefore come into relation with the annularis.

4. Is shaped something like an old-fashioned ∫; the concavity of the lower curve embraces the palmar and ulnar surfaces of the annularis, whilst that of the upper curve covers the palmar interosseus of the same space.

B.—Palmar.

1. Is, as has already been mentioned, triangular in shape, and is applied against the ulnar side of the index, its base being directed towards the palmar surface of the hand.

2. Occupies the lower half of the ulnar side of the third interspace, and lies on the palmar half, the radial side of the annularis, whose lower surface it curves round and covers.

3. Covers the lower two-thirds of the radial side of the minimus, the upper surface of the muscle, as well as the upper third of the bone, being covered by the palmar interosseus of the same space.

LUMBRICALES.

I have thought it unnecessary to allude earlier to these small muscles. It is sufficient to say that four were present in each of the hands described.

[Besides the sections described in this Paper, I have also figured (Plate IV., Fig. 5) a very beautiful and typical section through the centre of the metacarpus of a more advanced fœtus than any examined by me, which has been most kindly lent me for the purpose by Professor Cunningham. I have not thought it necessary to describe it, as it only differs in a few trivial details from the one last described; but I have figured it, as it will be necessary for the completion of some points which I am anxious to bring out.]

It appears to me that a short recapitulation of the changes of position undergone by the muscles will assist in drawing conclusions as to their history. Commencing with the Dorsal Interossei. The *first* of these muscles arrives very early at its adult position. In the first hand it only fills one half of its interspace, and reaches to the junction of the middle and superior third of the index in its course to the dorsum; but in the second manus it has arrived at the position which it finally occupies.

The *second dorsal interosseus* passes through a very curious series of changes of position. In the first hand it is situated in the lower part of the second interspace, its dorsally-directed apex reaching about half way up the side of the medius. In the second hand the index and medius have

approximated so closely to one another as to leave no space in the centre of the interval for a muscle to lie; and we find the interosseus, at present under review, situated well up on the dorsum of the hand, on the dorsal surface of the index, whilst its apex is directed towards the palm of the hand. Passing on to the third hand, we find that the bones have again divaricated, and that two-thirds of the second interspace is occupied by the muscle. Its apex is still directed towards the palm of the hand, and its broad dorsal base overtops its fellow palmar interosseus. Thus in the third hand this muscle arrives at its final situation. The *third dorsal interosseus*, in the first hand, does not even enter the third interspace; in the second it fills the entire of the space, with the exception of one small corner, and extends nearly as high towards the dorsum as do the tops of the medius. In the third hand, however, it occupies rather more than the radial half of the interspace, the growth of its palmar fellow having displaced it sidewards. This position it maintains in the fifth hand. Thus it also reaches its ultimate destination in the third hand. The *fourth dorsal interosseus* is slower in assuming its position than any of its fellows: in the first hand it reaches to about the middle of the annularis. In the second hand it has not risen higher, though its fibres do not extend so deeply into the palm as in the previous section. In the third hand it extends somewhat higher up, and is excluded from the lower one-third of the space by its palmar fellow. It occupies only the middle third of the interspace, the division between the muscles being transverse.

In the fourth hand, however, it has made a great stride, occupies nearly the whole of the space, and not only so, but also covers about one-half of the palmar surface of the annularis.

In the section of the hand given to me by Professor Cunningham, which I shall allude to from henceforth as the fifth hand, it reaches its complete position, occupying the radio-dorsal half of the diagonally-divided fourth interspace.

Before coming to any general conclusion with regard to these muscles, it will be well, briefly, to review the changes undergone by the palmar interossei, as the two groups are so closely connected with one another that it is impossible to discuss either separately.

The first palmar interosseus in the first hand encroaches for only a very small amount on the second interspace; in the second it has risen a little higher, though not much; whilst in the third it has established itself in its permanent situation, occupying the ulno-palmar half of the diagonally-divided interspace.

The second palmar interosseus does not enter the third interspace in either of the first two hands; it has, however, in the third hand made such progress that it is found in its final position.

The third palmar interosseus barely encroaches upon the interspace at all in the first hand; in the second it has advanced a little further towards the dorsum, but still projects down into the palm; in the third it occupies the entire of the lower third of the interspace; in the fourth section, however, it takes up the position almost exactly which it occupies in the fifth, and which it adheres to in the adult condition.

From the review which we have just finished of these muscles we shall, I think, be able to form the following conclusions :—

1. The first dorsal interosseus is the earliest to take up the position which it occupies in the adult hand, and the remaining interossei, both palmar and dorsal, take up their positions in order from without inwards. Thus the first dorsal arrives at its destination in the second hand; the second and third dorsal, and the first and second palmar, in the third; whilst the fourth dorsal and third palmar do not do so until the fifth hand.

Although the muscles of the second and third interspaces appear to violate slightly this rule by both arriving at their goal in the same hand, yet I think that this violation is more apparent than real, and for this reason: there is a considerable distance in point of development between a fœtus of 5 cms. and one of 7 cms., H. B. M., and I think that we may very fairly conclude that in a section of the hand of a fœtus of 6 cms., H. B. M., we should find the muscles of the second interspace adult in their position, whilst those of the third would be as yet immature as regards theirs.*

* Since this Paper was read I have had the opportunity of examining the hand of a fœtus of 6 cms., H. B.M., and I find in it that the condition which I had ventured to predict is that which actually obtains. *Birmingham, December*, 1882.

2. There is no fusion whatsoever between the dorsal and palmar interossei even at the earliest times.

3. The history briefly sketched of these muscles is as follows:—Both groups exist at an early period in the palmar aspect of the bones. The dorsal group then rise severally to positions between the bones. Then the palmar interossei push their way up between the bones, and thus produce the appearance which is so well marked in the later sections of a muscular square between the bones, divided diagonally. This fully bears out the conclusions which Ruge has previously come to in his Paper already mentioned.*

With regard to the muscles of the Thenar Region, without going to the length of a recapitulation of their appearances, which, however requisite in the case of the last muscles, is unnecessary here, we may, I think, form the following deductions:—

1. The abductor pollicis, very early, indeed, assumes the shape on section which it possesses in the adult hand. It is full and rounded superficially, whilst its deep surface is concave. It has a thick rounded radial margin, and a thin sharp ulnar extremity.

2. The study of these sections seems to point decidedly to the derivation from the flexor brevis of the opponens. Such a division indeed can be seen in the process of taking place in the smallest hand. Several questions of great interest arise with regard to this, viz:—Does the fission begin above and extend downwards, or *vice versa*? At what point is it best marked? These points could only be definitely settled by a series of oblique and longitudinal sections, and unfortunately my supply of material has been too scanty to permit of my making investigations by this method.

3. As a minor point of some interest, I may allude to the fact that in the fœtus of 7 cms., H. B. M., the fibres of the adductor transversus are carried on to the palmar surface of the annularis. This would appear to point to a period when a greater grasping power was exercised by the hand, and thus would seem to be in favour of the hypothesis of our having possessed

* *Loc. ant. cit.*

arboreal predecessors. This is not a point, however, on which I wish to lay too much stress.

4. The muscle known as the interosseus primus volaris of Henle, which has been spoken of in this Paper as the flexor brevis pollicis, caput profundum, has already had a passing notice taken of it. It appears to me that it would be of interest to trace it through the various hands. First, however, let me again draw attention to the remarks of Bischoff. He says, "Der innere Kopf des flexor brevis pollicis ist nämlich bei den Menschen sehr schwach und wie beim Orang und Hylobates ganz durch den adductor obliquus in der Tiefe gedrängt, so dass er erst nach Entfernung desselben sichtbar wird." He then goes on to state what I have before mentioned with regard to the short muscles of the thumb. He says, "Er." (fl. br. poll. cap. prof.), "ist bisher entweder gar nicht beachtet, oder von Dursy und Henle unter der Bezeichnung der interosseus internus i. oder pollicis et indicis beschrieben worden. Was man gewöhnlich bei uns als inneren Kopf des flexor brevis beschreibt, ist der adductor obliquus." If these statements be true, we should expect to find the muscle under discussion at first larger in proportion and less dorsally placed, and gradually becoming smaller relatively to its fellow interossei and being driven further towards the dorsum of the hand.

We have now to see how far the evidence of the sections will support such inferences. In the first hand the muscle stands in a wonderfully distinct series with the remaining palmar interossei. It is nearly equal in size to any of them, and is larger than the third. It is situated at about the middle of the ulnar surface of the pollex. In the second hand I fail to find this muscle. The only reason I can give for this failure is, that all the fibres of the short muscles of the thumb are so massed together in this section that it is very hard to distinguish any one fasciculus from another. In the third hand, however, it is very distinct, smaller than any save the third, which it about equals in size, and holding much the same position as regards the metacarpal bone. In the fourth hand it is much smaller than any of the interossei, and is nearer towards the dorsum of the hand. In the fifth its size is much the same. It is on the dorsal portion of the ulnar surface of the pollex, and is in very close contiguity with the fibres of the adductor transversus.

I think that these facts are fully sufficient to bear out the inferences which have been drawn. In Bischoff's work* a figure is given of this muscle as it exists in the human hand. The view is taken from the front, and the interosseus primus volaris is to be seen between the flexor brevis pollicis (cap. superfic.) and adductor obliquus. It is drawn to the front by a slip placed underneath it. It can, however, be much more easily seen from the dorsum of the hand. The proper way to arrive at it in a dissection is to work from the dorsal surface towards the palm, when on removing the superficial tissues and first dorsal interosseus it is brought into view.

With regard to the muscles of the Hypothenar Region, I only wish to make one remark. From the fact that the abductor and flexor brevis are so much more inseparably united in the older hands, it appears that they are originally more or less distinct, and that in process of growth a fusion takes place. In those cases, therefore, in the adult hand in which the flexor brevis is said to be absent, the fact really is, that it is so completely fused with the abductor as to be unrecognizable.

This concludes my observations on the subject of the embryology of the short muscles of the hand, and I have only to regret that I have not been able to make my study of it as complete and satisfactory as could be wished.

A description of the comparative anatomy of the short muscles of the hand throughout the Vertebrata, with a comparison of the conditions obtaining in the various classes with stages in the development of the human hand, would form an interesting and appropriate sequel to this Paper.

* *Op. supra cit.*

DESCRIPTION OF PLATES III. and IV.

The reference to Sections are the same throughout all the Figures.

M^1. M^2. M^3. M^4. M^5. Metacarpals of pollex, index, medius, annularis, and minimus.

i. Abductor minimi digiti.
ii. Flexor brevis minimi digiti.
iii. Opponens minimi digiti.

A. Abductor pollicis.
B. Opponens pollicis.
C. Flexor brevis pollicis (caput superficiale).
D. ,, ,, ,, (,, profundum).
E. Adductor obliquus.
F. ,, transversus.

LL. Lumbricales.

* Tendon of flexor longus pollicis.

D^1. D^2. D^3. D^4. First, second, third, and fourth dorsal interossei.
P^1. P^2. P^3. First, second, and third palmar interossei.

PLATE III.

Sections through Manus of Fœtus of 2·4 cms. H. B. M.

Fig. 1. Through bases of metacarpal bones.

Y. Abductor and possibly fibres of flexor brevis.

Fig. 2. Approximately through centre of metacarpal bone.

Sections through Manus of Fœtus of 5 cms. H. B. M.

Fig. 3. Through second row of carpus.

X. Abductor pollicis (chiefly).

Z. Hypothenar muscles.

A. { Un. Unciform. / M. Os magnum. / Td. Trapezoid. / Tm. Trapezium.

Fig. 4. Through bases of metacarpal bones.

Fig. 5. Through centre of metacarpal bones (approximately).

α. Tendon of flexor carpi radialis.

β. Anterior annular ligament.

γ. Tendon of palmaris longus.

PLATE IV.

Sections through Manus of Fœtus of 7 cms. H. B. M.

Fig. 1. Through bases of metacarpal bones.

ω. Palmaris brevis.

Fig. 2. Through centre of metacarpal bones (approximately).

ξ. Cartilaginous nodule, bound to ulnar side of minimus by ligaments, into which the muscular bundle ii., iii. is attached.

Sections through Manus of Fœtus of 12 cms. H. B. M.

Fig. 3. Through bases of metacarpal bones.

Fig. 4. Through centre of metacarpal bones (approximately).

Fig. 5. Section approximately through centre of metacarpal bones, from a fœtus of more advanced age (from a section kindly lent me by Professor Cunningham).

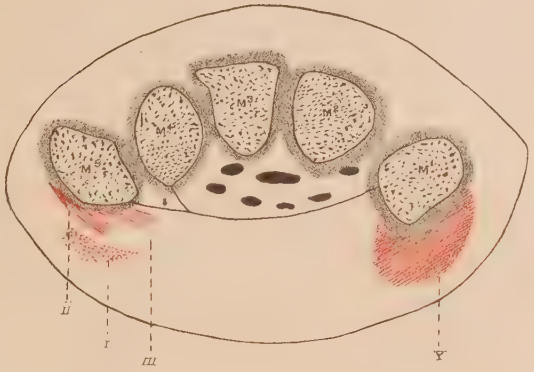


Fig. 1.

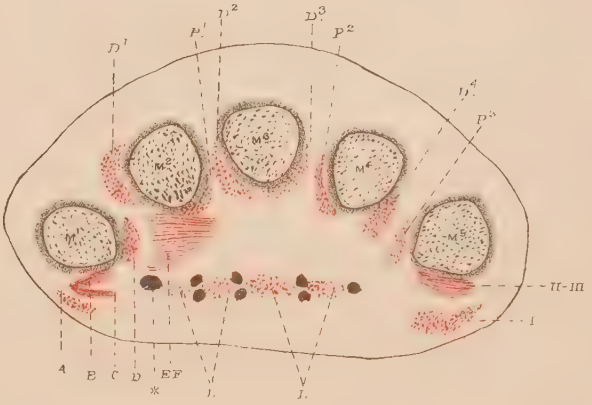


Fig 2.

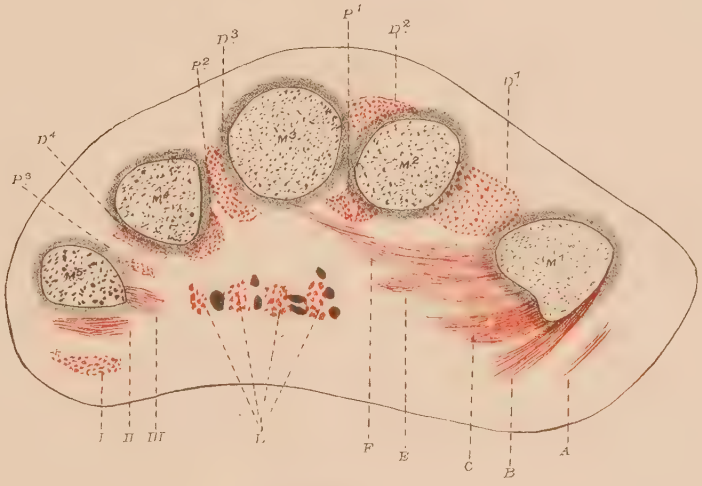


Fig. 5.

Fig. 3

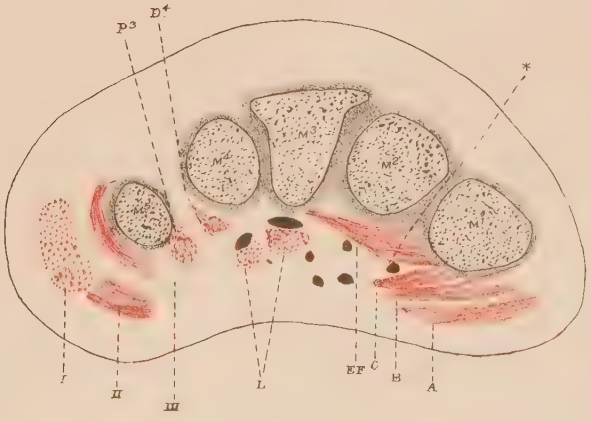


Fig. 4

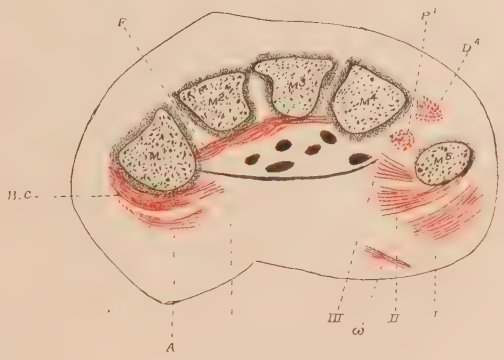


Fig. 1.

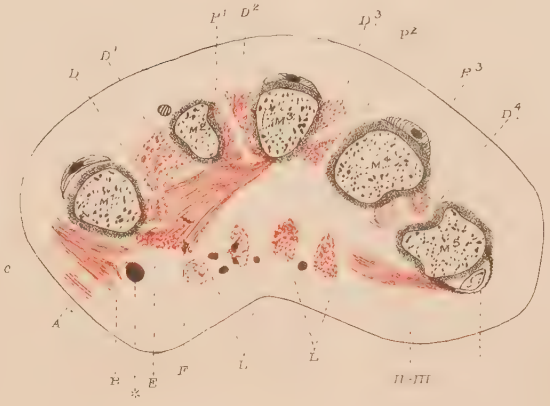


Fig. 2

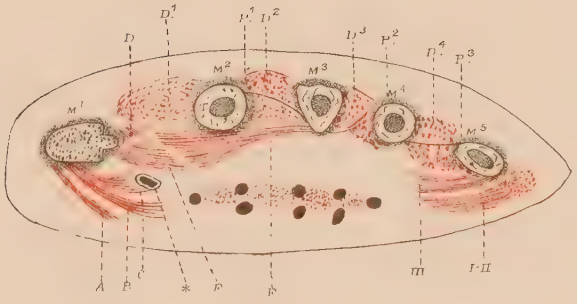


Fig 5.

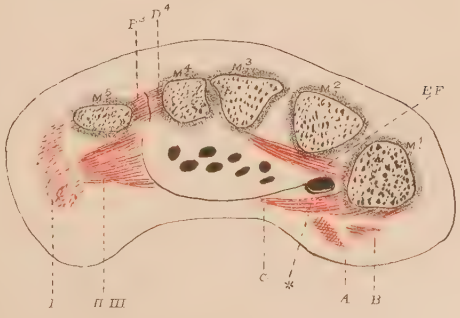


Fig. 3.

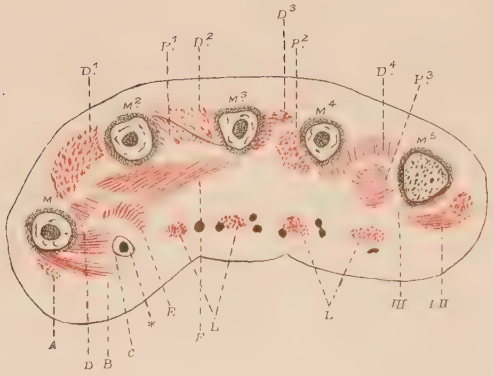


Fig. 4.

B C A. W. ad nat. del.

West, Newman & Co. Lith.

XIII.—*Report on the Acanthology of the Desmosticha.* (Part II.) By H. W. Mackintosh, M.A., M.R.I.A., Professor of Zoology, and Curator of the Museum of Anatomy and Zoology in the University of Dublin. [With Plates V. to VIII.]

[Read, June 26th, 1882.]

It is now about two years since Professor Alexander Agassiz added another to the many kindnesses which he has conferred upon me, by offering to place in my hands for examination and description a collection of sections of the spines of Echini. The offer was gladly accepted, as, besides the advantage of examining authentically-named specimens, it saved me the labour—no inconsiderable one—of preparing the sections myself. Various causes have prevented my taking up the work until now, when I am enabled to present to the Academy this, the second, part of my "Report on the Acanthology of the Desmosticha."

The collection sent to me by Professor Agassiz consists of about a hundred and fifty slides, illustrating the structure of the spines of the families Arbaciadæ, Echinometridæ, and Echinidæ. Of the first of these nearly all the species are represented, the two others, relatively large groups, being less fully illustrated. The only drawback to the value of the collection is, that the parts of the spines from which the sections are taken are not indicated; and though in most cases this can be decided with considerable certainty, still the inferences may not always be correct. I have in my own collection some slides representing some of the species included

amongst those sent by Professor Agassiz, and have thus been able to institute comparisons and extend my examination further. I have also thought it advisable to have fresh drawings made of some of the forms figured in the first part of my Report.

Before proceeding to describe the structure of the spines of the various species, it is right to notice some criticisms with which Professor Agassiz has honoured me in his interesting "Report on the Challenger Echinoids." And first let me repeat here what I have already stated, that, in urging the value of acanthological characters as taxonomic features, I do not wish to make them the basis of a classification which should replace all other systems. My object in the memoir to which Professor Agassiz refers* was partly to show the connexions and divergences between the various genera, and partly to introduce into zoological literature a system of terminology by which the various acanthological characters might be conveniently expressed. I cannot but think that, just as a diagnosis of, for instance, any genus of Gasteropoda should include, in order to be complete, a description of the odontophore, so that of a Desmostichan should include a notice of the structure of its spines. It may be that I did not make this sufficiently clear, and that consequently Professor Agassiz has inferred that I wished to make acanthology the basis of Echinoid taxonomy. My reason for presenting the terminology proposed there in a tabular form was to render its plan more easily understood and more readily remembered.

Passing on from this, I wish to notice one or two points wherein Professor Agassiz takes exception to my conclusions. He does not think that the mere fact of the Diadematidæ having hollow spines affords reason for contrasting them with the spines of all the other Desmosticha, and prefers to regard them as monocyclic Acanthosphenota which have more or less lost the central pith. This is very possibly the case, but I do not see that it furnishes any reason against taking the character as a differential one, at least until it is proved to occur indiscriminately in the other groups. As a rule, the Diadematidæ are acanthocœlate, whilst the other groups, as a rule, are not. Again, Professor Agassiz urges that the structural

* "On the Acanthology of the Desmosticha," these *Transactions*, vol. xxvi., p. 475.

features of the spines make their appearance far on in the embryonic history, the spines of young Echini, so far as we know them, being practically identical in structure. It seems to me, so far as I can understand the embryonic—or, perhaps, I ought to say larval—changes of Echini, that the pore areas and abactinal system are at least as late in assuming their characteristic arrangement, and yet no one denies their taxonomic value. Again, Professor Agassiz says: "The very fact that we have among the Echinoids the anomalies to which Mackintosh refers shows us plainly that the derivation from the original embryonic type has not gone on during growth equally in all the genera of the same family, some of the genera retaining a much more embryonic (*i.e.* simple fenestrate) condition than others." If this argument be valid as against acanthological characters, it must be equally so as against anal systems; and when we find Parasalenia, for instance, retaining the embryonic feature of four anal plates, whilst the other Echinometridæ have a large number, we must conclude that the abactinal system is not a safe generic character either. Nor can I agree with Professor Agassiz that the Cidaridæ present us with the most complicated type of spine structure; for, so far as I have been able to make out, they approach most nearly to the fundamental type, as shown in the stems of Crinoids, the spines of Asteroids and Ophiurans, &c., the external sheath being added as an adaptive modification to prevent the softer internal part from being too rapidly worn away. It may be due to my own want of perception, but I am free to admit that I cannot see that my position is materially weakened by Professor Agassiz's criticism, there being, as I have already said, no single characteristic feature which may not be objected to on some grounds, and be found to break down in some direction, when applied as a taxonomic test. It is superfluous to add, save for the pleasure of doing so, that Professor Agassiz's remarks are marked by the same spirit which has already found expression in many acts of courtesy to myself.

I shall now take up the description of the acanthological characters of the genera, commencing with those belonging to the family Arbaciadæ, and following the plan adopted in my first Paper on the subject.*

* *Transactions*, vol. xxv., p. 519, *et seq.*

ARBACIADÆ (Gray).

This family includes three genera—Arbacia (Gray), Podocidaris (A. Agass.), and Cœlopleurus (Agass.), which contain respectively six, two, and two, species, according to Agassiz. Of these I have examined sections of the spines of five species of Arbacia, and both the species of Cœlopleurus. Agassiz gives a figure of a section of one of the spines of *Podocidaris sculpta* (A. Agass.) in his Revision, but it is not a satisfactory one, and he is tantalizingly silent as regards the spine structure of *P. prionigera* (A. Agass.), only telling us a little about its external appearance.

The diagnoses based upon the materials at my command will run as follows:—

ARBACIA (Gray).

Spines acanthosphenote, monocyclic; the wedges usually with a long, slender stalk, then suddenly expanding; sometimes of nearly uniform slenderness throughout; external crust present only in the distal extremity, where it forms a kind of cap.

As already mentioned, I have been able to examine sections of the spines of five out of the six species, included under this genus by A. Agassiz, and give drawings of them in Plate V., figs. 1 to 9. I am inclined to think they are mostly taken from near the median region of the spine in each case, with the exception of fig. 6, which represents a section through the head of *A. pustulosa*, unless I am very greatly mistaken in interpreting its structure. An examination of the figures will show that the five species can be distinguished from each other fairly well by means of the differences obtaining in the arrangement of the solid wedges.* Thus in *A. stellata* (Gray) (Plate V., fig. 1), the solid wedges are reduced to mere spokes, reminding us strongly of the structure seen in a Cidarid spine, if we omit the crust (*vide* "Acanthology of Desmosticha" (*l. c.*), Plate IX., figs. 8, 9). In *A. spatuligera* (A. Agass.) (Plate V., fig. 2) the wedges are more strongly marked, and

* I have not examined the spines of *Arbacia Dufresnii* (Gray). They are said by A. Agassiz to "correspond closely to the general appearance of the spines of *A. punctulata*," but this would seem to have reference only to their external character.

the pith is of considerable extent; in *A. nigra* (Gray) (Plate V., fig. 3), the solid wedges are still larger, whilst the pith is relatively less extensive; in *A. punctulata* (Gray) (Plate V., figs. 4, 5), the wedges show distinct "heads" attached to long stalks; and, lastly, in *A. pustulosa* (Gray) (Plate V., figs. 6 to 9), the peripheral parts of the solid wedges have reached their maximum relatively to the rest of the spine, being in some places only separated from each other by very narrow strips of reticular tissue. It will be noticed that in the section through the head of the spine of *A. pustulosa*, figured at Plate V., fig. 6, the wedges are well developed, though of course less conspicuous than in the shaft of the spine. The material at present to hand being so small, it would be premature to decide how far the differences indicated above will hold for each species, but I have thought it desirable to publish figures of them as a contribution towards our knowledge of specific characters of spine structure. The specific affinities indicated above, however, do not correspond particularly well with the relationships of the species as deduced from other characters by Agassiz. Thus *A. stellata* comes nearest to *A. punctulata*, whilst *A. spatuligera* is intermediate between *A. nigra* and *A. pustulosa*. Until more data are forthcoming we will not be able to settle this point.

CŒLOPLEURUS (Agassiz).

Acanthostracan; central pith surrounded by a ring of large foramina; remainder of spine composed of close, uniform, reticular tissue; solid wedges not well marked; crust thin, sometimes scarcely discriminable. This is an exceedingly remarkable genus of Desmosticha, possessed of a small Arbacia-like test, with very long, curved, primary spines. The above diagnosis is constructed from an examination of sections of the primary spines of the two species, coupled with the figure published by A. Agassiz of a section of the primary spine of *C. Maillardi* ("Report on the Challenger Echinoids"), but this latter differs not a little from my figure, the crust being thicker and the solid wedges much better marked. The structure changes somewhat in the smaller spines, the reticulated tissue becoming much coarser and less homogeneous, until, in what Agassiz calls the smaller spines, the

figure shows a network of stout bars, enclosing large oval foramina, with scarcely any crust differentiated; a condition which, as Agassiz remarks, is very much like that shown by the spines of *Podocidaris sculpta* (A. Agass.)—an interesting fact, as the spines of this species, as shown by the figure in the "Revision of the Echini," possess so peculiar a structure as to have rendered it hitherto a matter of considerable difficulty to determine their relation to any other genus from an acanthological point of view. The figures published by Agassiz in the "Challenger Echini," however, settle this difficulty, and show plainly that Podocidaris connects through Cœlopleurus with Arbacia. A glance at the figures of the two species of Cœlopleurus will show that, so far as they are concerned, the spines of *C. floridanus* (A. Agass.) (Plate VI., fig. 10), can be distinguished from those of *C. Maillardi* (A. Agass.) (Plate VI., fig. 11), by the possession of a relatively larger pith, rather better marked solid wedges, and a scarcely discriminable crust. At the same time it must be borne in mind that the section of the spine of *C. Maillardi*, published by A. Agassiz in the "Challenger Echini," shows very well-marked, solid wedges, and the outline is circular, though the description would certainly seem to imply that the primary spines are always more or less angular in section.

ECHINOMETRIDÆ.

This family is one of the larger groups of the Desmosticha, thirty-two species being included in it, according to Professor Agassiz's "Revision," and it is a somewhat difficult one as regards the arrangement of its species, the two genera, Echinometra and Strongylocentrotus, being variable to a high degree as regards the contained forms. Thus, for instance, in Agassiz's Synonymic Index may be found no less than fifty-four species which have been at one time or another referred to the genus Echinometra, which indicates the amount of variation which writers seem to have permitted to the characters of the genus. Professor Agassiz, whether rightly or wrongly, has reduced the number of species to six, and curiously enough the Challenger Expedition has not afforded any new species of this family.

The collection of sections lent to me by Professor Agassiz includes the following species:—

Colobocentrotus atratus (Brandt).
Heterocentrotus mammillatus (Brandt).
,, *trigonarius* (Brandt).
Echinometra lucunter (Blain.)
,, *oblonga* (Blain.)
,, *subangularis* (Desml.)
,, *van Brunti* (A. Agass.)
,, *viridis* (A. Agass.)
Parasalenia gratiosa (A. Agass.)
Stomopneustes variolaris (A. Agass.)
Strongylocentrotus depressus (A. Agass.)
,, *eurythrogrammus* (A. Agass.)
,, *Dröbachiensis* (A. Agass.)
,, *purpuratus* (A. Agass.)
,, *lividus* (Brandt).
Echinostrephus molare (A. Agass.)

In addition to these I have examined sections of the spines of *Strongylocentrotus mexicanus* (A. Agass.); *S. tuberculatus* (Brandt); *S. armiger* (A. Agass.); and *Sphaerechinus pulcherrimus* (A. Agass.); but though this is a considerable proportion of the admitted species, it cannot be regarded as at all a satisfactory investigation of the group, as the number of described species is so very much greater. Hence the results here submitted are to be regarded as purely tentative, pending a more thorough study of the acanthology of the family. For this reason I do not think it would be desirable to attempt to give generic and specific diagnoses of spine structure; with the present limited knowledge the attempt would be premature, and the characters would probably require reconstruction according as the contained forms were worked out. I shall, therefore, both with this family and the Echinidæ, content myself with taking a survey of the group, and indicating the features which I think will prove to be those on which diagnoses will turn.

The Echinometridæ are all acanthosphenote, and, so far as we know, more or less distinctly polycylic, Parasalenia being an exception. The relative proportion between the reticular tissue and the solid wedges varies very greatly. At one end we have Heterocentrotus, Colobocentrotus, and Stomopneustes, in which the small solid wedges are scarcely discernible amongst the abundant reticulations; and at the other we have such forms as *Strongylocentrotus lividus* (Plate VII., fig. 23), or Echinostrephus (Plate VII., fig. 24), in which the greater part of the spine is composed of solid wedges, and the network is small in amount. Between these two extremes we have every intermediate condition, the greatest range of variation being found perhaps in Strongylocentrotus, where we find *S. lividus* (Plate VII., fig. 23), with scarcely any reticular tissue, and *S. tuberculatus* with a very large amount of it. I will now briefly pass in review the acanthological characters of the species which I have examined, and append drawings of the greater number of them.

The genus Colobocentrotus (Brandt) is remarkable, at least as regards one species, for the possession of a number of short, thick spines in the upper surface of the corona, which form a kind of pavement, and must contribute not a little to give it the strength which is demanded by the animal's habit of clinging to rocks "exposed to the full fury of a Pacific Ocean swell." Round the equator of the shell the spines become longer, and show in cross-section an oval contour, with a number of small solid wedges, and a large quantity of reticular tissue. This is the structure as found in *C. atratus* (Brandt) (Plate VI., fig. 18), the only one with whose acanthology I am acquainted. It leads us naturally to Heterocentrotus, with which it is fairly closely allied, and from which it differs acanthologically, not alone in the shape of the spine, which seems to be invariably that of a flattened ellipse, but also in the greater distinctness of the solid wedges from each other, their larger relative size, and, as a rule, the large number of cycles of growth in a spine. At the same time it is to be noticed that, apart from the shape, the structural differences are very small.

Heterocentrotus (Brandt) also contains two species remarkable for the large size which the spines frequently attain. I have examined sections of the spines of both species, but although it is possible to distinguish the two

in some cases, I am not at all certain that spines might not be found which would be practically indistinguishable. Professor Agassiz states that the spines—at least as regards their external form—are utterly useless as specific distinctions, as the mere fact of accident and repair will suffice to cause *H. mammillatus* to grow spines like *H. trigonarius*, and *vice versâ*. The distinguishing features of the spine structure are the small size and large number of the solid wedges, the peripheral series of which projecting on the surface give the spines their characteristically fine striation. The reticular tissue is also very close, and so a section of a spine looks almost homogeneous, especially under a low power. The only structural difference I have been able to detect in the specimens I have examined is that the solid wedges in *H. trigonarius* are more strongly marked and longer than in *H. mammillatus*, in which they are short and broad, and show a greater tendency to run into each other. In markedly typical specimens we find also that the spines of *H. trigonarius* are angular, whilst those of *H. mammillatus* are circular in section, but this is by no means a constant feature. Stomopneustes (Agass.) seems to approach Heterocentrotus most nearly in the structure of its spines, differing, however, in the prominence of the solid wedges, which are very well marked and somewhat crescentic in outline; there are, moreover, many more cycles of growth in this genus than in Heterocentrotus in proportion to the size of the spine. There is, so far, only a single species of this genus, *S. variolaris* (Agass.), and its acanthological characters are so strongly marked as to leave little or no difficulty in recognizing it. There have been a few other forms, referred by Agassiz to this species, which have been described under different names, but all the specimens I have examined differ in no sensible degree from the description given by Agassiz, and therefore may be assumed to be typical forms; whether those described under different names would turn out to have a different spine structure remains to be seen.

The genus Echinometra (Rond.) is less easily disposed of. The structure of the spines, so far as I have examined it, is very characteristic of the genus, there being a series of well-marked, solid wedges, with alternate dilatations and contractions, separated from each other by spokes of reticular tissue, which here consists of tubules excavated in the solid substance of the

spine. The contracted parts of the solid wedges correspond of course to dilatations in the reticular tissue, and *vice versâ*. The distinctness and regularity of the arrangement of the two structures in the spines of this genus cause them to present exceedingly pretty appearances under the microscope, and hence we find that most books on the microscope contain figures more or less accurate of spine sections of Echinometra. But while the generic features would seem to be fairly well marked, it is quite another question when we come to deal with those of the species. Taking the forms figured,* there is no difficulty whatever in distinguishing *E. oblonga* (Plate VI., fig. 12), *E. subangularis* (Plate VI., fig. 13), and *E. van Brunti* (Plate VI., fig. 15) from each other and from the other two; and a little more careful inspection of the figure of *E. lucunter* (Plate VI., fig. 16) shows that it may be discriminated from *E. viridis* (Plate VI., fig. 14) by the larger size of the solid wedges and the greater distance from the pith at which the first cycle of wedges is placed. But whether these differences would hold in a large series of specimens is not yet certain, and whether some of the forms agreeing in other features might yet differ in acanthological characters also remains to be determined. There is only one species of which I have examined any considerable number of specimens, viz. *E. lucunter*, and I find that on the whole its spines are practically identical; at the same time it must be remembered that the genus is a very variable one as regards the characters of the contained species, and it would be very desirable to have full examinations made of the structure of the spines, as it might turn out that forms are included under the same species which might have to be kept separate. The drawings figured here will at least make a beginning in this direction.

It is equally difficult as yet to decide anything definitely concerning the acanthology of Strongylocentrotus (Brandt). This genus contains, according to Agassiz, fourteen species, of which I have been able to study only eight; and of these but few examples, with the exception of the well-known and common *S. lividus* (Br.) (Plate VII., fig. 23), of which I have examined a considerable number of specimens, and always with the same result as regards the structure of the spines. With the exception of this species, all

* The slight want of regularity to be noticed in some of the figures is due, I believe, to a slight degree of obliquity in the plane of section.

the others which I have so far seen are constructed somewhat on the same plan, there being a large number of distinct solid wedges, which are manifestly polycyclic, and as a rule project from the surface in strongly marked ridges. The general *facies* is that of Echinometra, but with a greater tendency for the dilated parts of the solid wedges to run together, so as to produce continuous cuneate outlines; a condition which attains a maximum in *S. lividus* (Plate VII., fig. 23), in which the solid pieces are distinctly wedge-shaped, and the cycles of growth are represented by concentric striations instead of by alternate expansions and contractions in the outlines of the wedges. Taking the material already to hand we find that, on the one side, such forms as *S. eurythrogrammus* (A. Agass.) (Plate VII., fig. 19) connect with Stomopneustes, and thence with Heterocentrotus and Colobocentrotus, the genera in which the solid wedges are reduced to a minimum, that thence the series runs through *S. tuberculatus* (Br.) and *S. Mexicanus* (A. Agass.), both of which closely resemble *S. eurythrogrammus*, on to the forms with larger solid wedges, such as *S. purpuratus* (A. Agass.) (Plate VII., fig. 20), *S. depressus* (A. Agass.) (Plate VII., fig. 21), *S. Dröbachiensis* (A. Agass.) (Plate VII., fig. 22), and *S. armiger* (A. Agass.) ("Acanthology of Desmosticha" (*l. c.*), Plate XI. fig. 24), species which lead us, acanthologically at least, towards Echinometra; whilst lying out, as it were, on the borders of the genus is *S. lividus* (Br.) (Plate VII., fig. 23), presenting an extraordinarily close resemblance to *Echinus esculentus* (Plate VIII., fig. 36) in the structure of its spines, a resemblance which is inexplicable unless it be due to homoplasy. I have little doubt that some of the other species of the genus as yet unexamined will furnish us with the links connecting *S. lividus* with what would appear to be the more typical structure of the genus.

The remaining genera of the family contain but few species, and can be briefly disposed of. Sphærechinus (Desor) contains three species, one of which, *S. pulcherrimus* (A. Agass.), I have been able to study to some extent, as it is rather common in collections. The spines ("Acanthology of Desmosticha" (*l. c.*), Plate X., fig. 16) remind us in their structure of *S. Dröbachiensis* and *S. lividus*, the solid wedges being more distinctly constricted at intervals than the latter, but less so than the former; while at the same time they

are not unlike the spines of many of the Echinidæ, a family with which Sphærechinus seems to me to have many points of affinity. Echinostrephus (A. Agass.), a genus containing but one species, *E. molare* (A. Agass.) (Plate VII., fig. 24), is more remarkable for the structure of the corona than for that of the spines. These are long and strong in proportion to the size of the test, which appears to be always small; in section they are not unlike those of Echinometra, but can be distinguished from them by the relatively larger size of the solid wedges and the greater coarseness of the reticulated tissue, the combined effect being to give a degree of distinctness to the pattern, and render them remarkably pretty microscopic objects.

Parasalenia (A. Agass.), another genus with but one species, *P. gratiosa* (A. Agass.), is a very interesting one, having affinities with Echinometridæ in the elliptic shape of the test, the arrangement of tubercles and the structure of the buccal membrane, and with Arbaciadæ in the arrangement of the anal system, which is composed of four plates, in the limited number of pairs of pores and in the structure of the spines (Plate VI., fig. 17), which are monocyclic, and very similar in plan to those of Arbaciadæ, as may be seen by comparing the figures, bearing in mind that the outer area of reticular tissue is the milled ring of the spine, and would not appear at all in a section taken a little higher up. I confess that the affinities of the genus seem to me to be more strongly marked in the direction of the Arbaciadæ than in that of the Echinometridæ, and I would be very much disposed to place Parasalenia in the former family, as the genus connecting it with Echinometridæ.

The only other genus of the Echinometridæ is Pseudoboletia (Troschel), but I have not been able to examine its spines. Professor Agassiz gives two figures of sections in the "Challenger Echini" which show a very anomalous structure, one of them being composed of an extraordinarily large amount of pith, with a row of small solid wedges stuck in, as it were, round the margin, whilst the other has a cycle of somewhat similarly shaped wedges attached to a ring round a central cavity like that of a Diadema. Professor Agassiz, as I have already said, calls attention to this fact as against my division of acanthocœlate and acanthodictyote spines. It would be interesting to determine whether the variability is constant for the genus.

ECHINIDÆ.

This is another of the larger families of the Desmosticha, and one about the acanthology of which we know very little. The spines of the genera Pleurechinus, Temnechinus, Holopneustes, Evechinus, and Prionechinus (one of the genera yielded by the Challenger), have either not been examined at all, or if examined have not been figured. Of the spine structure of Hemipedina there is an unsatisfactory photograph in the "Revision," and a still worse one of Trigonocidaris, so that the only genera with whose spine structure we are in any degree acquainted are Temnopleurus, Microcyphus, Salmacis, Amblypneustes, Phymosoma, Echinus, Hipponoë, and Toxopneustes. Several of the species belonging to these genera have not been studied from the acanthological side at all, and some are figured now for the first time, so that our knowledge of the group from this point of view is only in embryo; and my chief object in the present instance is to give some figures by way of a beginning, as it would be manifestly premature to construct or attempt to construct diagnoses of genera and species until our knowledge is more extended. Indeed the evidence from the material thus far to hand is so contradictory as to call for a thorough examination of the whole series; for if the acanthological evidence be taken into account, it would seem as if the present arrangement of species would have to be modified, there being at least one genus which seems to possess two different types of spine structure. This is the genus Temnopleurus (Agass.), which contains three species, *T. Hardwickii* (Agass.), *T. Reynaudi* (Agass.), and *T. toreumaticus* (Agass.). I give drawings of sections of the spines of the three species, an examination of which will render it evident that there are—at least as regards the specimens thus far studied—two plans of structure. In *T. Hardwickii* (Plate VII., figs. 25, 26)* we have large solid wedges and a very small amount of reticular tissue, whilst in *T. Reynaudi* (Plate VII., fig. 27)

* Fig. 26 is drawn from a specimen marked *Microcyphus elegans*, a form which Agassiz seems to consider as identical with *Temnopl. Hardwickii*. Unless the wrong name has been accidentally put on the slide, it is not easy to explain the difference in structure.

the reverse condition obtains, and in *T. toreumaticus* (Plate VIII., fig. 28), if we accept the present arrangement of species, we have two very different plans of structure. In the one case (Plate VIII., fig. 28) we find polycyclic growth, and a circular contour, in the other ("Acanthology," Plate X., fig. 13), monocyclic growth and an elliptic contour; and the *facies* of the two is so different that if they were placed side by side one would unhesitatingly say they belonged to different genera. It may be said that such cases as these prove that acanthological characters are valueless as means of specific or generic discrimination, but until further evidence is forthcoming such an assertion is a *petitio principii*. As soon as it is shown in a fair number of cases that specimens, agreeing in all other specific characters, differ notably in the structure of their spines, I am quite willing to abandon my present position, but, so long as the evidence in favour of it is as strong as it is at present, I prefer to abide by it.

A form such as *T. Hardwickii* connects readily with *Microcyphus maculatus* (Agass.) (Plate VIII., fig. 29), where we have the same large, solid wedges and reduced reticular tissue. There is another species of this genus, but I do not know anything of its spine structure. If one might hazard an opinion, based on the very shadowy photograph of the section of the spine of *Trigonocidaris albida* (A. Agass.), given in the "Revision," one would say that this genus was very much like Microcyphus in the structure of its spines, though it is possible there may be a central cavity. It is to be regretted that more knowledge of the acanthology of this genus is not forthcoming, it being a very interesting one from a structural point of view.

Of the genus Salmacis (Agass.) I have been able to examine sections of spines of two out of the five species. These are *S. bicolor* (Agass.) (Plate VIII., fig. 30) and *S. rarispina* (Agass.) ("Acanthology of Desmosticha" (*l. c.*), Plate X., fig. 15). The specimen of *S. bicolor* figured is noteworthy as presenting a central cavity, a condition not unfrequent in this sub-family, and one which lends some force to Professor Agassiz's criticism of my proposal to regard the Diadematidæ as the typical acanthocœlate group. The two forms figured agree well in general characters, whilst remaining sufficiently distinct the one from the other, the solid wedges in *S. bicolor* tapering

rapidly to very slender stems, whilst those in *S. rarispina* slope off more gradually. They both connect well with the spines of Temnopleurus, and also, as I pointed out in the first part of my Report, with those of Amblypneustes. The only other genus of the sub-family Temnopleuridæ, the spines of which I have examined, is Mespilia (Des.), which contains a single species, *M. globulus* (Agass.) The section figured from the collection lent me by Professor Agassiz (Plate VIII., fig. 31) will be found to differ considerably from that figured in the previous part of my Report (*l. c.*) (Plate X., fig. 14). I am inclined now to think that the latter was a section of a spine which had been repaired after injury. This might easily be the case, the small size of the spine (one-seventieth of an inch in diameter) rendering it difficult to determine whether it was normal or injured. The specimen figured here will be seen to be distinctly polycyclic, and is remarkable for the substantial character of its solid wedges.

The sub-family Triplechinidæ contains six genera. Of the acanthology of one of these, Evechinus (Verrill), there is no description; and of another, Hemipedina, the photograph in the "Revision" is unsatisfactory; it would appear, however, to bear a general resemblance in its spine structure to *Phymosoma crenulare* (A. Agass.) (Plate VIII., fig. 32), which is remarkable for the small amount of pith, and still more for the extreme slenderness of the solid wedges, which take the form of rods, very much like those of the Cidaridæ. There is, however, no external crust. The smallness of the pith and the slenderness of the solid wedges impart a striking and characteristic appearance to the spines of this genus.

The acanthology of the genus Echinus is illustrated by sections of four species, *E. acutus* (Lamk.) (Plate VIII., fig. 33); *E. elegans* (Düb. o. Kor.) (Plate VIII., fig. 34); *E. Norvegicus* (Düb. o. Kor.) (Plate VIII., fig. 35); and *E. esculentus* (Linn) (Plate VIII., fig. 36). It is the largest genus of the sub-family, and to some extent resembles Strongylocentrotus in the structure of its spines. They are markedly polycyclic—at least so far as we know—and differ from each other, as will be seen in the drawings, in a way which renders it easy to distinguish one from the other. In *E. esculentus* (Plate VIII., fig. 36) the solid wedges are very prominent and the general arrangement reminds us of that of *S. lividus* (Plate VII., fig. 23); in *E. elegans*

(Plate VIII., fig. 34), remarkable for the beauty of its colouring no less than for the elegance of its structure, the solid wedges are also well marked, but, being more strongly constricted at intervals, admit of the existence of a larger amount of reticular tissue, which, increasing yet more in *E. Norvegicus* (Plate VIII., fig. 35), reaches a maximum (in the series figured) in *E. acutus* (Plate VIII., fig. 33), a species the structure of whose spine resembles that of *Hipponoë esculenta* (A. Agass.) (Plate VIII., fig. 37), the only member of this genus included in the collection. A comparison of the section figured here with that of *H. variegata* (A. Agass.) figured in my Report (*l.c.*), would go to show that the spines of this genus possess a large amount of axial reticular tissue, and well-marked cycles of growth.

There are no sections of the spines of Toxopneustes in the series lent me by Professor Agassiz, and I am hence unable to add anything to what is stated in my previous Report, in which will be found a figure of the spine structure of a specimen which seems to be *T. maculatus* (A. Agass.)

EXPLANATION OF PLATES V., VI., VII., and VIII.

The drawings have been done for me by Mr. Horace Knight, and I avail myself of this opportunity of acknowledging the care he has bestowed on them, and their fidelity to the originals. The drawings themselves are sufficient evidence of Mr. Knight's artistic skill and delicacy of touch. They are all drawings of transverse sections of spines.

PLATE V.

Fig. 1. *Arbacia stellata.*

Fig. 2. *A. spatuligera.*—The black-edged markings in the pith are air bubbles which occurred in the preparation.

Fig. 3. *A. nigra.*

Figs. 4 & 5. *A. punctulata.*—It is possible that these are sections of spines of the same specimen, but from different parts of the test; it seems more likely, however, that they are from different specimens.

Fig. 6. *A. pustulosa.*—Probably a section of the head just below the milled ring, the solid wedges being well marked and the circumference of the section even.

Figs. 7, 8, 9. *A. pustulosa.*—The two former probably different spines of the same specimen; the third from a different specimen.

PLATE VI.

Fig. 10. *Cœlopleurus floridanus.*—The spine is seen to be composed mainly of reticular tissue, the solid wedges appearing merely as thin rods; the crust is scarcely distinguishable.

Fig. 11. *C. Maillardii.*—In this spine the crust is distinctly seen.

Fig. 12. *Echinometra oblonga.*

Fig. 13. *E. subangularis.*

Fig. 14. *E. viridis.*

Fig. 15. *E. van Brunti.*

Fig. 16. *E. lucunter.*—The excentric position of the pith in this specimen is, I apprehend, due to a slight obliquity in the plane of section, the result being that the successive cycles appear crowded on one side and remote from each other on the opposite.

Fig. 17. *Parasalenia gratiosa.*—Showing the monocyclic character of the spines like those of Arbacia. The section is taken through the milled ring of the spine, which shows as dense reticular tissue on the periphery.

Fig. 18. *Colobocentrotus atratus.*

PLATE VII.

Fig. 19. *Strongylocentrotus eurythrogrammus.*—The solid wedges appear as slender rods with slight thickenings at intervals.

Fig. 20. *S. purpuratus.*—The inner row of solid wedges which is seen in this section is not apparent in another specimen.

Fig. 21. *S. depressus.*—A similar condition exists here as in the last.

Fig. 22. *S. Dröbachiensis.*

Fig. 23. *S. lividus.*

In the series thus given, a successive increase in the prominence of the solid wedges will be noticed.

Fig. 24. *Echinostrephus molare.*—The spine is constructed on the general plan of an Echinometra, but the details are relatively coarser.

Fig. 25. *Temnopleurus Hardwickii.*

Fig. 26. *T. Hardwickii* (*Microcyphus elegans*).

Fig. 27. *T. Reynaudi.*

PLATE VIII.

Fig. 28. *T. toreumaticus.*—There is another section of a spine of this species in the collection in which the solid wedges are more broadly cuneate and come into contact towards the circumference; *vide* remarks on this genus, p. 253.

Fig. 29. *Microcyphus maculatus.*—The markings seen in the solid wedges are cracks.

Fig. 30. *Salmacis bicolor.*—The solid wedges consist of a long, slender inner part, which suddenly expands into a wide wedge-shaped portion.

Fig. 31. *Mespilia globulus.*—Showing a distinctly polycyclic arrangement.

Fig. 32. *Phymosoma crenulare.*—In this genus the solid pieces are linear and the spine has consequently somewhat the appearance of that of a Cidarid, but without the peripheral crust.

Fig. 33. *Echinus acutus.*

Fig. 34. *Echinus elegans.*

Fig. 35. *Echinus Norvegicus.*

Fig. 36. *Echinus esculentus.*

In this series there is apparent, as in the series of Strongylocentrotus, a successive increase in the size of the solid wedges.

Fig. 37. *Hipponoë esculenta.*

Fig. 1 × 40.

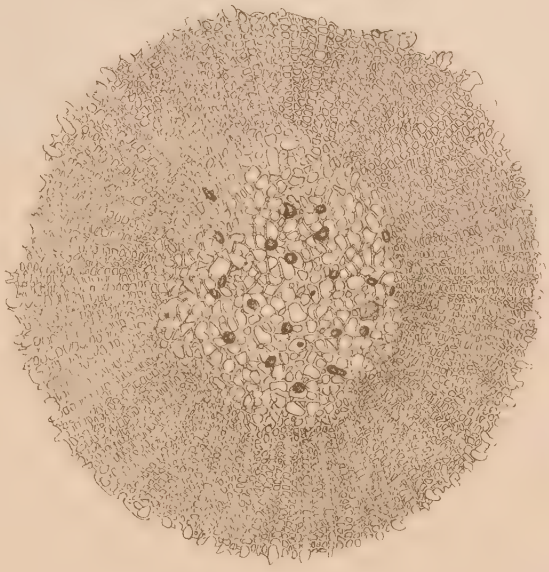


Fig 2. × 38.

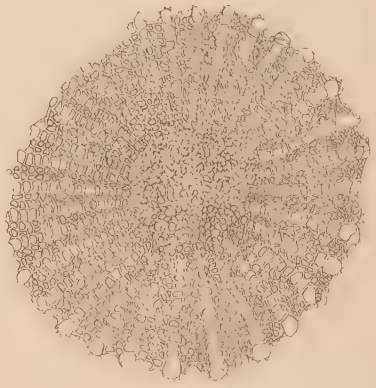


Fig. 3 × 35.

Fig. 4 × 37.

Fig. 5 × 40.

Fig 8 × 50

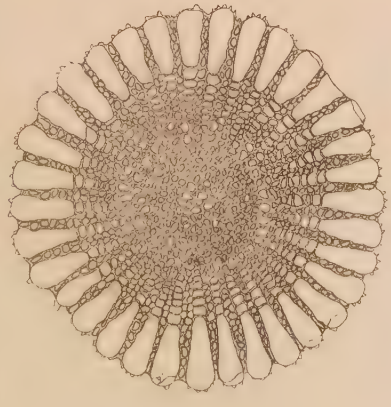


Fig 7 × 40

Fig 6 × 45.

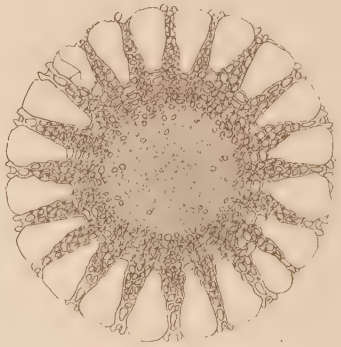


Fig 9. × 46

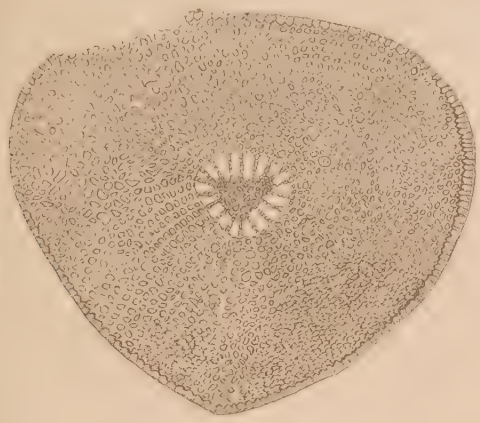


Fig 11 × 37

Fig 10 × 33

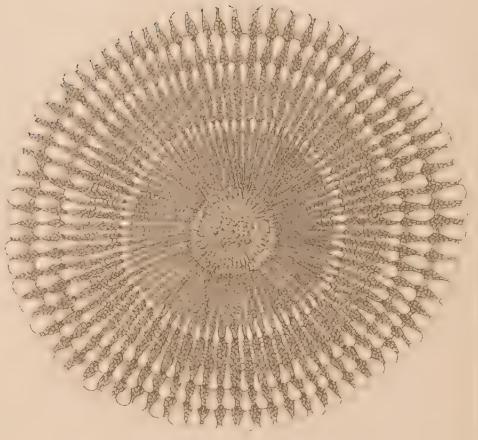


Fig. 12. × 18

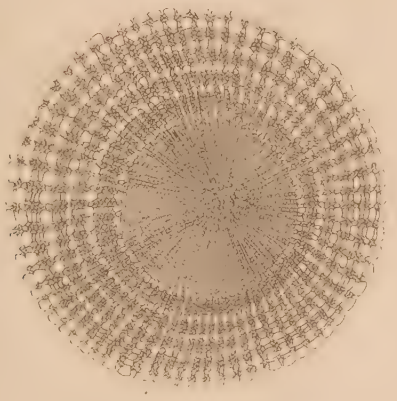


Fig. 15 × 23

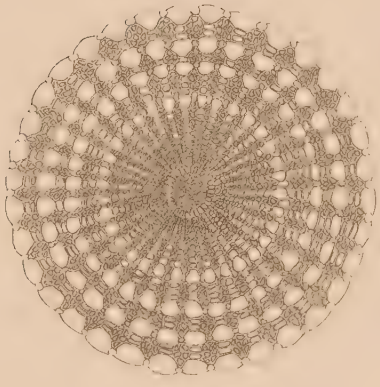


Fig 14 × 33

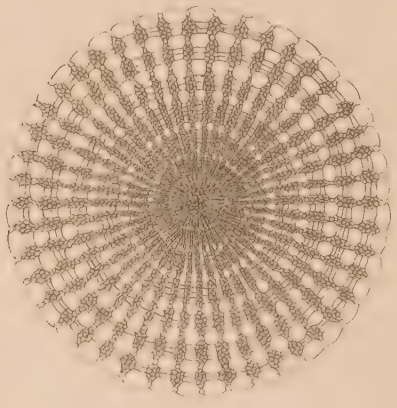


Fig 13 × 36

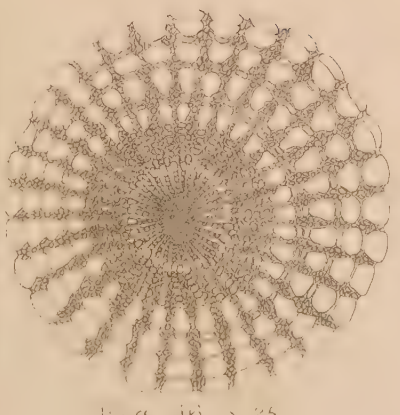


Fig 16 × 25.

Fig. 18 × 16

Fig 17 × 32

Horace Knight ad nat. del.

West Newman & C° lith

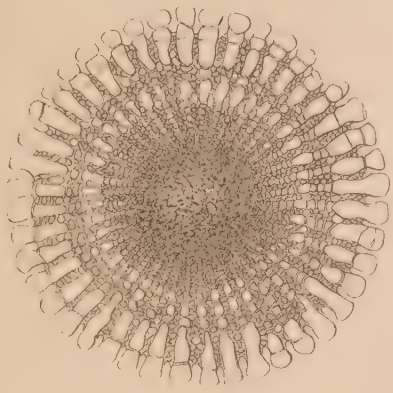


Fig 20 × 40

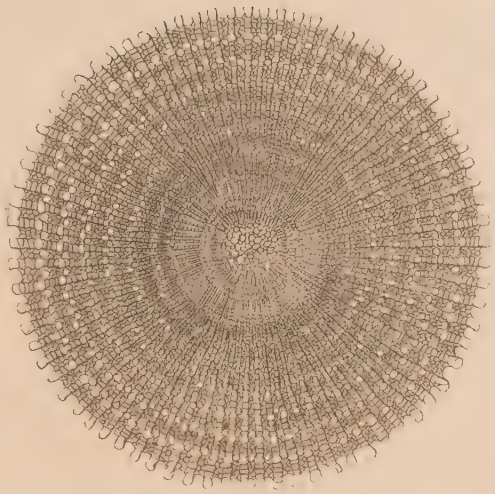


Fig. 19 × 13

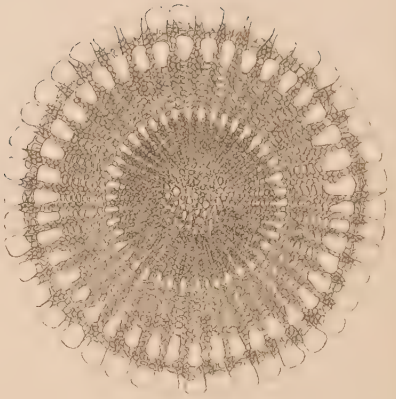


Fig 21 × 36

Fig. 22 × 44

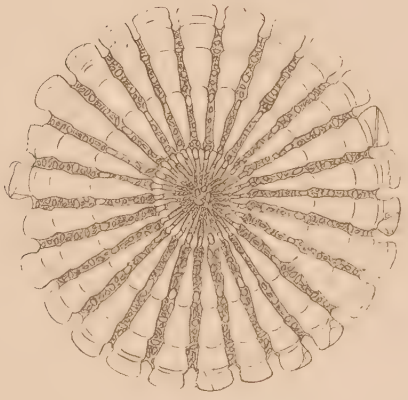


Fig. 23 × 48.

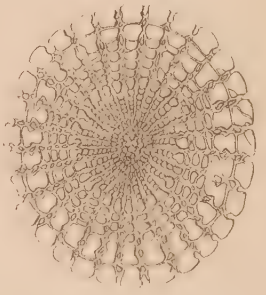


Fig 24 × 50

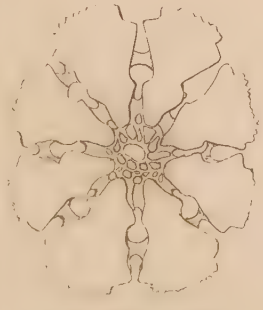


Fig 25 × 130

Fig. 26 × 60

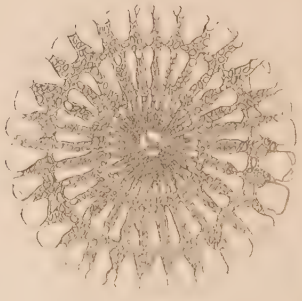


Fig 27 × 75

Horace Knight ad nat. del.

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XIV.—*Report on the Acanthology of the Desmosticha.* (Part III.) *Further observations on the Acanthology of the Diadematidæ.*

By H. W. Mackintosh, M.A., M.R.I.A., Professor of Zoology, and Curator of the Museum of Anatomy and Zoology in the University of Dublin. [With Plates IX. and X.]

[Read, June 26th, 1882.]

In this part of my Report I wish to give the result of some observations in extension and correction of the Paper on the Structure of the Spines of the Diadematidæ, which I laid before the Academy in 1875.* I am indebted for the materials enabling me to do so to the kindness of Professor Dr. Peters of Berlin and to Dr. Günther of the British Museum. When I wrote my former Paper I was under the impression that a specimen of *Centrostephanus Rodgersii*, in the Museum of Trinity College, was *C. longispinus*, and it was not until Dr. Peters sent me specimens of the spines of the true *C. longispinus* that I found out my mistake. By that time, however, the sheets had been printed off, and it was too late to correct the error. In the present Paper I propose to describe the structure of those spines, and to add a few details of interest which I have since discovered.

One of the most interesting of these is the presence of dimorphic spines in a specimen of *Diadema Mexicanum* from California, which I owe to the kindness of Dr. Günther. I cannot find any notice of dimorphic spines occurring in this genus in the "Revision of the Echini," nor are they to be seen in the other specimens of this species which I have had the opportunity of examining, but they are quite unmistakeable in this one, there being the

* These *Transactions*, vol. xxv., p. 519, *et seq.*

usual long tapering verticillate spines with the normal Diadema structure which occur all over the test, and a limited number of fusiform ones placed on the actinal surface. These are about half an inch in length, are longitudinally striated, not verticillate, as Diadema spines mostly are, and in section show a structure very comparable to that of the fusiform spines of *Centrostephanus Rodgersii*. It is also interesting that on the same specimen there occur a few spines which present characters intermediate in some ways between the other two. They are somewhat fusiform in outline, but are distinctly verticillate and but faintly striated, are longer than the true fusiform spines, but never so long as the conical ones, and in section show a considerable proportion of reticular tissue, though not nearly so much as the true fusiform ones; in fact they exhibit much the same difference from the structure of a typical conical spine, as I found to exist in the spines of a specimen of *Diadema antillarum* (Phil.), a form which Agassiz considers to be only a variety of *D. setosum* (*vide l. c.*, Plate XXXI.,* "Researches on Diadematidæ"). This interesting specimen goes to show that the existence of dimorphic spines is not as characteristic of the genus Centrostephanus as I had believed. I have given a full series of figures of sections of the spines, from which an idea of the structure can be gathered sufficiently to render a verbal description unnecessary (Plate IX., figs. 1, 2, 3, 4, 6).

CENTROSTEPHANUS (Peters).

In my former Paper I gave the result of my examination of what I now know to have been two specimens of *C. Rodgersii* (A. Agass.), though at the time I thought one of them was *C. longispinus* (Peters). Professor Peters having kindly sent me specimens of the spines of this species, I am able to give drawings of sections. In this species the fusiform spines seem to be exceedingly minute, that sent me by Dr. Peters being about one-eighth of an inch in length, and composed, so far as I could make out, entirely of reticular tissue. Whether we can regard this as a fusiform spine at all is, I think, doubtful; it might very easily prove to be only a very young conical spine. A. Agassiz, however, alludes to the fact that Phillippi, who first described

the species, mentions that there were short club-shaped spines of a bright vermilion colour in the upper part of the test near the abactinal system. They do not seem to have been present, however, in Dr. Peters' specimen, and so perhaps fusiform spines are variable here as in Diadema. As regards the conical spines, the figures show that they can be readily distinguished from those of their congener. They are fully as long but much more slender, and instead of the uniform dark purple coloration of *C. Rodgersii*, they are marked with alternate bands of red and straw colour. In section the spine has very much the appearance of that of a Diadema; the wedges are cuneiform, not urceolate, and there is rather less reticular tissue at the base than in *C. Rodgersii*, whilst at the same time they differ from Diadema in that they are not so long in proportion to their width. The milled ring (Plate IX., fig. 8) is remarkable for its large size, and here we have a more distinctly urceolate outline to the solid wedges. In the head (Plate IX., fig. 7) they are represented as usual by linear calcifications. The amended diagnosis of acanthological characters for the genus will run somewhat as follows:—

Spines dimorphic. Fusiform spines fewer in number and shorter than the conical spines, without verticillations, and with longitudinal striations. Conical spines long, verticillate; in section showing a large central hollow; foraminated ring rather slender, sinuous; reticular tissue scanty; solid wedges urceolate or broadly cuneiform.

The characters of the two species examined will stand thus:—

C. longispinus (Peters).—Fusiform spines very small, and apparently composed of reticular tissue. Conical spines chiefly composed of solid wedges, cuneiform in outline, the width being about one-third of the height (Plate IX., figs. 7–9; Plate X., figs. 10, 11).

C. Rodgersii (A. Agassiz).—Fusiform spines moderate; solid wedges small, urceolate, with long stalks which are surrounded by copious reticular tissue. Conical spines long; solid wedges large, urceolate, with short stalks and scanty reticular tissue (Plate IX., fig. 5; Plate X., fig. 12).

ECHINOTHRIX (Peters).

In my former Paper I alluded to the great difference in spine-structure which was to be found between *E. calamaris* (A. Agass.) and *E. turcarum* (Peters), and hazarded the suggestion that the former was a divergence from the Echinothrix type which was to be found in *E. turcarum*. An examination of the acanthology of *E. Desorii* (Peters), which the courtesy of Dr. Peters has enabled me to carry on, makes against this supposition, for it shows a greater affinity to *E. calamaris* than to *E. turcarum*, as a comparison of the figures will at once render evident. It will be seen that the amount of reticular tissue is small,* that the solid wedges are elongate and joined by transverse bars, as in *E. calamaris*, and that the foraminated ring is also large, as in that species. I have also examined the spines of a form described by Peters under the name of *E. annellata*, and sent to me by him. They show in the main a structure similar to that found in *E. calamaris* and *E. Desorii*, of which latter this species is regarded as a variety by A. Agassiz. These considerations would indicate that *E. turcarum* is the aberrant type, and the difficulty of framing a diagnosis which will take in satisfactorily the acanthological characters of the three species is as great as ever. I may point out here, that so far as the materials thus far to hand go, *E. Desorii* may be distinguished acanthologically from *E. calamaris* by the relatively smaller size of the central cavity and the greater length of the solid wedges.

In addition to the foregoing, I have examined a single section of a spine of *Asthenosoma hystrix* (Wy. Thomson). It will be seen by the drawing (Plate X., fig. 19) that it resembles in structure the striated spines of *A. varium* (cf. "Researches," Plate XXXIII., fig. 35), from which, however, it can be readily distinguished by the larger size of the central cavity, the smaller amount of reticular tissue, and the greater distinctness of the

* I am disposed to think that the larger amount of reticular tissue to be seen in the median section (Plate X., fig. 15), as compared with the others, is due to the fact that the spine from which it was taken has been repaired.

foraminated ring. As, however, I have not been able to make a complete examination of the spines of this species, I refrain from attempting a reconstruction of the acanthological diagnosis, and content myself with giving a figure of the section.

Before concluding this part of my Report, I wish briefly to notice the new Diadematidæ and Echinothuridæ described by A. Agassiz in his interesting "Report on the Echini of the Challenger." There are two new genera, Aspidodiadema and Micropyga, containing respectively two and one species, besides which five new species have been added to Grube's genus Asthenosoma, and six to Wyville Thomson's genus Phormosoma. Of these fourteen new species, Professor Agassiz has published figures of the acanthology of eight; from which, and from his descriptions, so many interesting facts can be gleaned, that one cannot but regret that circumstances prevented his giving more particulars and full-sized drawings, the plan of giving a drawing of only a small part of a spine moderately amplified, together with a still smaller part more highly magnified, being to my mind a not very satisfactory one, inasmuch as it is very difficult to get a clear idea of the general arrangement by piecing together the fragments. It would, moreover, have been an advantage to have had the amplification indicated in each case.

The spines of *Micropyga tuberculatum* (A. Agass.) are very interesting. In it we find two kinds of spines, the actinal surface bearing conical, the abactinal club-shaped, spines. In the expanded part of the latter there is a dense central pith, an unusual character amongst Diadematidæ, whilst the conical spines show features which Professor Agassiz compares to those of Astropyga, but which seem to me to be more like those of *Echinothrix calamaris* (Plate X., fig. 17). The drawing of the section of the club-shaped spine is not at all distinct, and so it is not easy to speak with certainty; but, except for the presence of the pith in the club-shaped spines, there would appear to be in the genus a condition of dimorphic spine structure parallel to that which obtains in *C. Rodgersii* or in *D. Mexicanum*.

Aspidodiadema, the other new genus, is a very remarkable one, presenting, as Professor Agassiz well shows, intermediate characters between Cidaridæ and Diadematidæ. The spines are here also provided with a

central pith, and in general appearance seem to me to be not unlike those of Micropyga, but more coarsely and strongly built. The tissue of the pith and of the region between this and the peripheral wedges is remarkably open—far more so than in any Cidarid spine which I have ever seen. They are said by Agassiz to possess the coarse reticulation of a spine of Porocidaris or Salenia, but from the drawings they appear to be much coarser.

Of the genus Asthenosoma (Grube), Professor Agassiz gives drawings of sections of the spines of *A. Grubii* (A. Agass.) and of *A. pellucidum* (A. Agass.), which show features agreeing well with the structure shown by *A. varium* and *A. hystrix*.

Of Wyville Thomson's remarkable genus Phormosoma there are a considerable number of sections of spines figured, belonging to the species *Ph. tenue* (A. Agass.), *Ph. luculentum* (A. Agass.), and *Ph. hoplacantha* (Wy. Thoms.); but the value of the figures is seriously lessened by the fact that there is not any indication of the part of the spine from which the section is taken, a point of no little importance in such curiously formed spines as are those of this genus. In the general description of the acanthology, Professor Agassiz says that the structure agrees in the main with that of Asthenosoma, and inserts references to the drawings. One of the sections of a spine of *Ph. hoplacantha* seems from the drawings to have a structure like that of *Micropyga tuberculatum;* others are like *A. varium*, whilst others again seem to be *sui generis*. The presence of the large "hoofs," as Professor Agassiz calls them, is a striking feature in the spines of some species of this genus.

EXPLANATION OF PLATES IX. and X.

The drawings are of transverse sections only, and have been done under a Wollaston *camera lucida*.

PLATE IX.

Diadema Mexicanum.

Fig. 1. Section through milled ring of fusiform spine. The solid wedges are somewhat urceolate, and there are remains of a central reticulation.

Fig. 2. Section through proximal region of fusiform spine, showing the abundant reticular tissue and the long stalks of the solid wedges.

Fig. 3. Section through proximal region of conical spine.

Fig. 4. Section through proximal region of "intermediate spine," showing the presence of a considerable amount of reticular tissue, whilst the solid wedges retain their cuneiform outline.

Fig. 5. Section of fusiform spine of *Centrostephanus Rodgersii*.

Fig. 6. Section through distal region of "intermediate" spine.

Centrostephanus longispinus.

Fig. 7. Section through head of conical spine. The solid wedges are in the form of bars.

Fig. 8. Section through milled ring. The solid wedges are becoming wider in proportion to the length.

Fig. 9. Section through proximal region. The solid wedges are cuneiform in outline.

PLATE X.

Centrostephanus longispinus.

Fig. 10. Section through median region. Some of the solid wedges appear irregular in shape, in consequence of portions of the verticillations remaining attached to their extremities.

Fig. 11. Section through distal region.

Fig. 12. Section of conical spine of *C. Rodgersii*.

Echinothrix Desorii.

Fig. 13. Section through milled ring. The linear solid pieces are joined by numerous bars.

Fig. 14. Section through proximal region. The irregularity in the shapes of the solid wedges is due to the closeness of the verticillations, which causes a variable amount of the verticils to adhere to the solid wedges in the section which is slightly oblique.

Fig. 15. Section through median region of a spine which has probably been injured and repaired.

Fig. 16. Section through distal region.

Fig. 17. Section of spine of *E. calamaris*.

Fig. 18. Section of spine of *E. turcarum* with large amount of reticular tissue.

Fig. 19. Section of spine of *Asthenosoma hystrix*.

Fig. 1 × 30

Fig. 2. × 30

Fig. 3. × 30

Fig. 4 × 30.

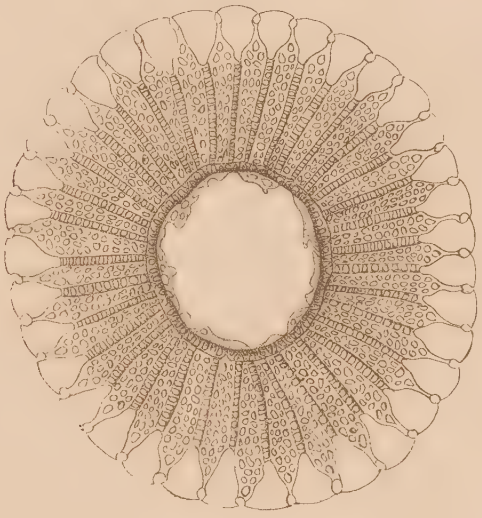

Fig. 5. × 30

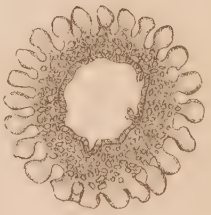

Fig. 6 × 30

Fig. 7 × 40

Fig. 8. × 35

Fig. 9. × 50.

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Fig. 10. × 45

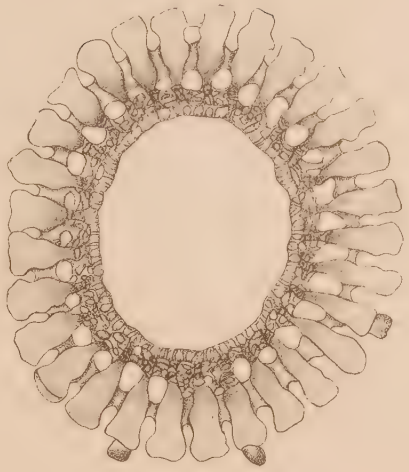


Fig. 12 × 20.

Fig. 11 × 55

Fig. 15 × 30.

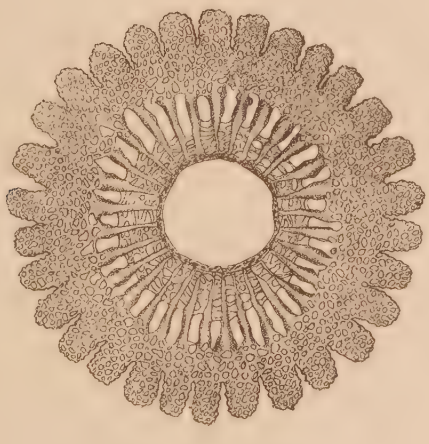


Fig. 13 × 20.

Fig. 14 × 20

Fig. 18 × 20

Fig. 16 × 45

Fig. 19 × 90.

Fig 17 × 33

XV.—*Expansion of Elliptic Functions.* By William Nicolls, B.A.

[Read, November 12th, 1883.]

1. When a function $\phi(x)$ is such that $\phi(n\lambda + x) = \phi(x)$, it is said to be periodic with respect to λ. When a function $\phi(x)$ is such that $\phi(n\mu + x) = \frac{1}{\phi(x)}$, we will call it reciprocally periodic with respect to μ.

The object of this Paper is to discuss the expansions in pairs of elliptic functions periodic with respect to $4K$, and reciprocally periodic with respect to iK'.

2. *Fourier's Theorem.*—When $\phi(x)$ is periodic with respect to λ, it can be expressed as follows :—

$$\phi(x) = A + \Sigma a_n \sin\frac{2\pi}{\lambda} nx + \Sigma b_n \cos\frac{2\pi}{\lambda} nx,$$

where

$$\Sigma a_n \sin\frac{2\pi}{\lambda} nx = a_1 \sin\frac{2\pi}{\lambda} x + a_2 \sin\frac{2\pi}{\lambda} . 2x + a_3 \sin\frac{2\pi}{\lambda} . 3x + \ldots$$

Cor. I.—When $\phi(x)$ changes sign with x;

then $$\phi(x) = \Sigma a_n \sin\frac{2\pi}{\lambda} nx.$$

Cor. II.—If, in addition to Cor. I., $\phi\left(x + \frac{\lambda}{2}\right) = \phi(x)$;

then $$\phi(x) = \Sigma a_{2n} \sin\frac{2\pi}{\lambda} . 2nx.$$

and in order that these two values of $\sin am\, u$ may be identical, we must have

$$a_n = (4 + a'_n)\, q^{\frac{n}{2}} = a'_n\, q^{-\frac{n}{2}};$$

therefore
$$a'_n = \frac{4q^n}{1-q^n}, \quad a_n = \frac{4q^{\frac{n}{2}}}{1-q^n};$$

therefore
$$\frac{2K}{\pi}\, k \sin am\, u = 4\Sigma \frac{q^{\frac{n}{2}}}{1-q^n} \sin nx \ . \ . \ . \ . \qquad (3)$$

$$\frac{2K}{\pi} \frac{1}{\sin am\, u} - \frac{1}{\sin x} = 4\Sigma \frac{q^n}{1-q^n} \sin nx \ . \ . \ . \ . \qquad (4)$$

4. To expand $k^2 \sin^2 am\, u$ and $\dfrac{1}{\sin^2 am\, u}$.

By Cor. V.,

$$\left(\frac{2K}{\pi}\right)^2 k^2 \sin^2 am\, u = A + \Sigma a_{2n} \cos 2nx, \ . \ . \ . \ . \qquad (5)$$

$$\left(\frac{2K}{\pi}\right)^2 \frac{1}{\sin^2 am\, u} - \frac{1}{\sin^2 x} = A' + \Sigma a'_{2n} \cos 2nx, \ . \ . \ . \ . \qquad (6)$$

In (6), change u into $iK' + u$, and x into $\dfrac{\pi i K'}{2K} + x$, and we get

$$\left(\frac{2K}{\pi}\right)^2 k^2 \sin^2 am\, u = A' - 4\Sigma n q^n e^{2nxi} + \tfrac{1}{2}\Sigma a'_{2n} \{q^n e^{2nxi} + q^{-n} e^{-2nxi}\}$$

$$= A' + \tfrac{1}{2}\Sigma [\{a'_{2n} - 8n\}\, q^n e^{2nxi} + a'_{2n} q^{-n} e^{-2nxi}].$$

And, comparing this result with (5), we get

$$A' = A; \ a_{2n} = \{a'_{2n} - 8n\}\, q^n = a'_{2n} q^n;$$

therefore
$$a'_{2n} = -\frac{8n q^{2n}}{1-q^{2n}}, \quad a_{2n} = -\frac{8n q^n}{1-q^{2n}}.$$

To determine A, integrate (5) between K and 0:

$$\frac{2K}{\pi}\int_0^K k^2 \sin^2 amu\, du = \int_0^{\frac{\pi}{2}} A dx;$$

therefore $$A = \frac{4K}{\pi^2}\int_0^K (1-\Delta^2 amu)\, du = \frac{4K}{\pi}\left(K - E\left(\frac{\pi}{2}\right)\right);$$

$$\therefore \left(\frac{2K}{\pi}\right)^2 k^2 \sin^2 amu = \frac{4K}{\pi}\left(K - E\left(\frac{\pi}{2}\right)\right) - 8\Sigma\frac{nq^n}{1-q^{2n}}\cos 2nx, \quad \ldots \quad (7)$$

$$\left(\frac{2K}{\pi}\right)^2 \frac{1}{\sin^2 amu} - \frac{1}{\sin^2 x} = \frac{4K}{\pi}\left(K - E\left(\frac{\pi}{2}\right)\right) - 8\Sigma\frac{nq^{2n}}{1-q^{2n}}\cos 2nx, \quad \ldots \quad (8)$$

5. To expand $\sin^3 amu$ and $\dfrac{1}{\sin^3 amu}$.

It can be easily seen that

$$\left(\frac{2K}{\pi}\right)^3 \frac{1}{\sin^3 amu} - \frac{1}{\sin^3 x} + \frac{b}{\sin x}, \text{ where } b = 1-(1+k^2)\left(\frac{2K}{\pi}\right)^2,$$

vanishes for $x = 0$. Hence, when n is an odd integer, by Cor. III.,

$$\left(\frac{2K}{\pi}\right)^3 k^3 \sin^3 amu = \Sigma a_n \sin nx \quad \ldots \quad (9)$$

$$\left(\frac{2K}{\pi}\right)^3 \frac{1}{\sin^3 amu} - \frac{1}{\sin^3 x} + \frac{b}{\sin x} = \Sigma a'_n \sin nx \quad \ldots \quad (10)$$

Employing the usual substitution in (10), we get

$$\left(\frac{2K}{\pi}\right)^3 k^3 \sin^3 amu - i\Sigma(n^2-1)\, q^{\frac{n}{2}} e^{2nxi} - ib\Sigma q^{\frac{n}{2}} e^{nxi} = -\frac{i}{2}\Sigma a'_n (q^{\frac{n}{2}} e^{nxi} - q^{-\frac{n}{2}} e^{-nxi});$$

therefore $$\left(\frac{2K}{\pi}\right)^3 k^3 \sin^3 amu = \frac{i}{2}\Sigma\left[\{2(n^2-1+b) - a'_n\}\, q^{\frac{n}{2}} e^{nxi} + a'_n q^{-\frac{n}{2}} e^{-nxi}\right];$$

therefore $$-a_n = \{2(n^2-1+b) - a'_n\}\, q^{\frac{n}{2}} = -a'_n q^{-\frac{n}{2}};$$

therefore $a'_n = -2(n^2 - 1 + b)\frac{q^n}{1-q^n} = 2\left\{(1+k^2)\left(\frac{2K}{\pi}\right)^2 - n^2\right\}\frac{q^n}{1-q^n}$

$$a_n = 2\left\{(1+k^2)\left(\frac{2K}{\pi}\right)^2 - n^2\right\}\frac{q^{\frac{n}{2}}}{1-q^n};$$

therefore $$\left(\frac{2K}{\pi}\right)^3 \sin^3 amu = 2\Sigma\left\{(1+k^2)\left(\frac{2K}{\pi}\right)^2 - n^2\right\}\frac{q^{\frac{n}{2}}}{1-q^n}\sin nx, \quad \ldots \quad (11)$$

$$\left(\frac{2K}{\pi}\right)^3 \frac{1}{\sin^3 amu} - \frac{1}{\sin^3 x} + \frac{b}{\sin x} = 2\Sigma\left\{(1+k^2)\left(\frac{2K}{\pi}\right)^2 - n^2\right\}\frac{q^n}{1-q^n}\sin nx; \quad \ldots \quad (12)$$

results which may be verified from the expansions of $\sin amu$ and $\frac{1}{\sin amu}$ by the identities

$$2k^2 \sin^3 amu \equiv \frac{d^2}{du^2}\sin amu + (1+k^2)\sin amu,$$

$$\frac{2}{\sin^3 amu} \equiv \frac{d^2}{du^2}\frac{1}{\sin amu} + (1+k^2)\frac{1}{\sin amu}.$$

6. To expand $\sin^4 amu$ and $\frac{1}{\sin^4 amu}$.

By Cor. V. $$\left(\frac{2K}{\pi}\right)^4 k^4 \sin^4 amu = A + \Sigma a_{2n}\cos 2nx, \quad \ldots \quad (13)$$

$$\left(\frac{2K}{\pi}\right)^4 \frac{1}{\sin^4 amu} - \frac{1}{\sin^4 amu} + \frac{b}{\sin^2 amu} = A + \Sigma a'_{2n}\cos 2nx, \qquad (14)$$

where $$b = \frac{2}{3}\left\{1 - (1+k^2)\left(\frac{2K}{\pi}\right)^2\right\}.$$

Employing the usual substitution in (14), we get

$$\left(\frac{2K}{\pi}\right)^4 k^4 \sin^4 amu = 16\Sigma\frac{n^3 - n}{6}q^n e^{2nxi} + 4b\Sigma n q^n e^{2nxi} + \tfrac{1}{2}\Sigma a'_{2n}\left(q^n e^{2nxi} + q^{-n}e^{-2nxi}\right)$$

$$= \tfrac{1}{2}\Sigma\left[\left\{a'_{2n} + 8bn + \frac{16}{3}(n^3 - n)\right\}q^n e^{2nxi} + a'_{2n}q^{-n}e^{-2nxi}\right];$$

therefore $a_{2n} = \left\{a'_{2n} + 8bn + \frac{16}{3}(n^3 - n)\right\} q^n = a'_{2n}\, q^{-n}$;

therefore $a'_{2n} = 8\left\{bn + \frac{2}{3}(n^3 - n)\right\} \frac{q^{2n}}{1 - q^{2n}} = -\frac{16}{3}\left\{(1 + k^2)\left(\frac{2K}{\pi}\right)^2 - n^2\right\} \frac{nq^{2n}}{1 - q^{2n}}$,

$$a_{2n} = -\frac{16}{3}\left\{(1 + k^2)\left(\frac{2K}{\pi}\right)^2 - n^2\right\} \frac{nq^n}{1 - q^{2n}}.$$

And $$A = \frac{1}{\pi}\left(\frac{2K}{\pi}\right)^2 \int_{-K}^{K} \frac{du}{\sin^4 amu} = \frac{4}{3}(1 + k^2) \frac{K - E}{\pi}\left(\frac{2K}{\pi}\right)^3 - \frac{1}{3} k^2 \left(\frac{2K}{\pi}\right)^4;$$

therefore

$$\left(\frac{2K}{\pi}\right)^4 \sin^4 amu = A - \frac{16}{3} \Sigma \left\{(1 + k^2)\left(\frac{2K}{\pi}\right)^2 - n^2\right\} \frac{nq^n}{1 + q^{2n}} \cos 2nx, \quad \ldots . \quad (15)$$

$$\left(\frac{2K}{\pi}\right)^4 \frac{1}{\sin^4 amu} - \frac{1}{\sin^4 x} + \frac{b}{\sin^2 x} = A - \frac{16}{3} \Sigma \left\{(1 + k^2)\left(\frac{2K}{\pi}\right)^2 - n^2\right\} \frac{nq^{2n}}{1 - q^2} \cos 2nx; \ldots \quad (16)$$

results which may be verified from the expansions for $\sin^2 amu$ and $\frac{1}{\sin^2 amu}$ by the identities

$$6k^2 \sin^4 amu \equiv \frac{d^2}{du^2} \sin^2 amu + 4(1 + k^2) \sin^2 amu - 2,$$

$$\frac{6}{\sin^4 amu} \equiv \frac{d^2}{du^2} \frac{1}{\sin^2 amu} + 4(1 + k^2) \frac{1}{\sin^2 amu} - 2k^2.$$

7. The expansions for $\cos amu$ and its powers may be derived from that of the sine and its powers by means of the well-known transformation which changes k, k', q, K, u, x, and $\sin amu$, into $\frac{ik}{k'}$, $\frac{1}{k'}$, $-q$, $k'K$, $k'u$, x, and $\cos am(K - u)$ respectively. We will, for illustration, give a direct proof of $k \cos amu$ and its reciprocally periodic function $\frac{\Delta amu}{\sin amu}$.

By Cors. VI. and III., when n is odd, we have

$$\left(\frac{2K}{\pi}\right) k \cos amu = \Sigma a_n \cos nx, \ldots . \quad (17)$$

$$\left(\frac{2K}{\pi}\right) \frac{\Delta amu}{\sin amu} - \frac{1}{\sin x} = \Sigma a'_n \sin nx, \ldots \quad (18)$$

Employing the usual substitution in (18), we get

$$-\left(\frac{2K}{\pi}\right) ik \cos amu + 2i\Sigma q^{\frac{n}{2}} e^{nxi} = -\frac{i}{2} \Sigma a'_n \left(q^{\frac{n}{2}} e^{nxi} - q^{-\frac{n}{2}} e^{-nxi}\right),$$

$$\left(\frac{2K}{\pi}\right) k \cos amu = \tfrac{1}{2} \Sigma \left\{(4 + a'_n) q^{\frac{n}{2}} e^{nxi} - a'_n q^{-\frac{n}{2}} e^{-nxi}\right\};$$

therefore $$a_n = (4 + a'_n) q^{\frac{n}{2}} = -q^{-\frac{n}{2}} a'_n;$$

therefore $$a'_n = -\frac{4q^{\frac{n}{2}}}{1+q^n}; \quad a_n = \frac{4q^{\frac{n}{2}}}{1+q^n};$$

therefore $$\left(\frac{2K}{\pi}\right) k \cos amu = 4\Sigma \frac{q^{\frac{n}{2}}}{1+q^n} \cos nx, \ldots . \quad (19)$$

$$\left(\frac{2K}{\pi}\right) \frac{\Delta amu}{\sin amu} - \frac{1}{\sin x} = -4\Sigma \frac{q^{\frac{n}{2}}}{1+q^n} \sin nx. \quad (20)$$

8. To expand Δamu and $\cot amu$.

By Cors. II. and V.,

$$\left(\frac{2K}{\pi}\right) \Delta amu = A + \Sigma a_{2n} \cos 2nx. \quad (21)$$

$$\left(\frac{2K}{\pi}\right) \cot amu - \cot x = \Sigma a'_{2n} \sin 2nx. \quad (22)$$

Employing the usual substitution in (22), we get

$$-\frac{2K}{\pi} i\Delta amu + i\frac{1+q e^{2xi}}{1-q e^{-2xi}} = -\frac{i}{2} \Sigma a'_{2n} \left(q^n e^{2nxi} - q^{-n} e^{-2nxi}\right);$$

therefore $$\frac{2K}{\pi}\Delta\, amu = 1 + 2\Sigma q^n e^{2nxi} + \tfrac{1}{2}\Sigma a'_{2n}\left(q_n e^{2nxi} - q^{-n}e^{-nxi}\right)$$

$$= 1 + \tfrac{1}{2}\Sigma\left\{(4 + a'_{2n})\, q^n e^{2nxi} + q^{-n}e^{-2nxi}a'_{2n}\right\};$$

therefore $$A = 1\ a_{2n} = (4 + a'_{2n})\, q^n = -\, q^{-n}a'_{2n};$$

therefore $$a'_{2n} = -\frac{4q^{2n}}{1+q^{2n}}, \quad a_{2n} = \frac{4q^n}{1+q^{2n}};$$

therefore $$\left(\frac{2K}{\pi}\right)\Delta\, amu = 1 + 4\Sigma\frac{q^n}{1+q^{2n}}\cos 2nx, \ \ldots\ . \qquad (23)$$

$$\left(\frac{2K}{\pi}\right)\cot amu - \cot x = -\Sigma\frac{q^{2n}}{1+q^{2n}}\sin 2nx. \ \ldots\ . \qquad (24)$$

9. To expand $\Delta^3 amu$ and $\cot^3 amu$.

By Cors. II. and V.,

$$\left(\frac{2K}{\pi}\right)^3\Delta^3\, amu = A + \Sigma a_{2n}\cos 2nx, \ \ldots\ . \qquad (25)$$

$$\left(\frac{2K}{\pi}\right)^3\cot^3 amu - \cot^3 x + b\,\cot x = \Sigma a'_{2n}\sin 2nx, \qquad (26)$$

where $$b = 1 + \frac{2-k^2}{2}\left(\frac{2K}{\pi}\right)^3.$$

Employing the usual substitution in (26), we get

$$\left(\frac{2K}{\pi}\right)^3 i\Delta^3 amu + i\left(\frac{1+qe^{2xi}}{1-qe^{-2xi}}\right)^3 - bi\,\frac{1+qe^{2xi}}{1-qe^{-2xi}} = -\frac{i}{2}\Sigma a'_{2n}(q^n e^{2nxi} - q^{-n}e^{-2nxi});$$

therefore

$$\left(\frac{2K}{\pi}\right)^3\Delta^3 amu = b - 1 - 2\Sigma(2n^2+1)q^n e^{2nxi} + 2b\Sigma q^n e^{2nxi} - \tfrac{1}{2}\Sigma a'_{2n}$$
$$(q^n e^{2nxi} - q^{-n}e^{-2nxi})$$

$$= b - 1 + \tfrac{1}{2}\Sigma\left[-\left\{4(2n^2+1-b) + a'_{2n}\right\}q^n e^{2nxi} + q^{-n}e^{-2nxi}a'_{2n}\right];$$

therefore $A = b - 1;\ a_{2n} = -\{4(2n^2+1-b) + a'_{2n}\}q^n = q^{-n}a'_{2n}$;

therefore $a'_{2n} = -4(2n^2+1-b)\dfrac{q^{2n}}{1+q^{2n}},\ a_{2n} = -4(2n^2+1-b)\dfrac{q^n}{1+q^{2n}}$;

therefore $$\left(\frac{2K}{\pi}\right)^3 \Delta^2 amu = b - 1 - 4\Sigma(2n^2+1-b)\frac{q^n}{1+q^{2n}}, \quad \ldots \quad (27)$$

$$\left(\frac{2K}{\pi}\right)^3 \cot^3 amu - \cot^3 x + b\cot x = \quad -4\Sigma(2n^2+1-b)\frac{q^{2n}}{1+q^{2n}} \ldots \quad (28)$$

10. To expand $\dfrac{\sin amu \cos amu}{\Delta amu}$ and $\dfrac{\Delta amu}{\sin amu \cos amu}$.

By Cor. VII.,

$$\left(\frac{2K}{\pi}\right)\frac{k^2 \sin amu \cos amu}{\Delta amu} = \Sigma a_{2(2n-1)} \sin 2(2n-1)x, \quad (29)$$

$$\left(\frac{2K}{\pi}\right)\frac{\Delta amu}{\sin amu \cos amu} - \frac{1}{\sin x \cos x} = \Sigma a'_{2(2n-1)} \sin 2(2n-1)x. \quad (30)$$

Employing the usual substitution in (30), we get

$$\frac{2K}{\pi}\frac{k^2 \sin amu \cos amu}{\Delta amu} = -4i\Sigma q^{2n-1} e^{2(2n-1)xi} - \frac{i}{2}\Sigma a'_{2(2n-1)}\{q^{(2n-1)} e^{2(2n-1)xi} - q^{-(2n-1)} e^{-2(2n-1)xi}\}$$

$$= -\frac{i}{2}\Sigma[(8 + a'_{2(2n-1)}) q^{(2n-1)} e^{2(2n-1)xi} - a'_{2(2n-1)} q^{-(2n-1)} e^{-2(2n-1)xi}];$$

therefore $a_{2(2n-1)} = (8 + a'_{2(2n-1)}) q^{(2n-1)} = q^{-(2n-1)} a'_{2(2n-1)}$;

therefore $a'_{2(2n-1)} = \dfrac{8q^{2(2n-1)}}{1-q^{2(2n-1)}} a_{2(2n-1)} = \dfrac{8q^{2n-1}}{1-q^{2(2n-1)}}$;

therefore

$$\frac{2K}{\pi}\frac{k^2 \sin amu \cos amu}{\Delta amu} = 8\Sigma\frac{q^{2n-1}}{1-q^{4n-2}} \sin(4n-2)x, \ldots \quad (31)$$

$$\frac{2K}{\pi}\frac{\Delta amu}{\sin amu \cos amu} - \frac{1}{\sin x \cos x} = 8\Sigma\frac{q^{4n-2}}{1-q^{4n-2}} \sin(4n-2)x. \quad (32)$$

(11). To expand the self-reciprocally periodic function log sin *amu*.

By Cor. V.,

$$\log \sin amu - \log \sin x = A + \Sigma a_{2n} \cos 2nx. \quad . \quad . \quad . \qquad (33)$$

Employing the usual substitution,

$$\log \frac{1}{k \sin amu} - \log \frac{q e^{2xi} - 1}{2iq^{\frac{1}{2}} e^{xi}} = A + \tfrac{1}{2}\Sigma a_{2n}(q^n e^{2nxi} + q^{-n} e^{-2nxi}).$$

But $$\log \sin x - \log \frac{e^{2xi} - 1}{2i e^{xi}} \equiv 0 ;$$

therefore

$$-\log k \sin amu + \log \sin x - \log \frac{(q e^{2xi} - 1)(e^{2xi} - 1)}{-4q^{\frac{1}{2}} e^{2xi}} = A + \tfrac{1}{2}\Sigma a_{2n}(q^n e^{2nxi} + q^{-n} e^{-2nxi});$$

therefore

$$\log \sin amu - \log \sin x + \log (1 - q e^{2xi})(1 - e^{-2xi}) - \log \frac{4q^{\frac{1}{2}}}{k}$$

$$= - A - \tfrac{1}{2}\Sigma a_{2n}(q^n e^{2nxi} + q^{-n} e^{-2nxi}) ;$$

therefore $\log \sin amu - \log \sin x$

$$= \log \frac{4q^{\frac{1}{2}}}{k} - A + \frac{1}{n} q^n e^{2nxi} + \Sigma \frac{1}{n} e^{-2nxi} - \tfrac{1}{2}\Sigma a_{2n}(q^n e^{2nxi} + q^{-n} e^{-2nxi})$$

$$= \log \frac{4q^{\frac{1}{2}}}{k} - A + \tfrac{1}{2}\Sigma \left\{ \left(\frac{2q^n}{n} - a_{2n} q^n \right) e^{2nxi} + \left(\frac{2}{n} - a_{2n} q^{-n} \right) e^{-2nxi} \right\} ;$$

therefore $$A = \tfrac{1}{2} \log \frac{4q^{\frac{1}{2}}}{k}, \quad a_{2n} = \frac{2q^n}{n} - a_{2n} q^n = \frac{2}{n} - a_{2n} q^{-n} ;$$

therefore $$a_{2n} = \frac{2}{n} \frac{q^n}{1 + q^n} ;$$

therefore $$\log \sin amu - \log \sin x = \tfrac{1}{2} \log \frac{4q^{\frac{1}{2}}}{k} + 2\Sigma \frac{1}{n} \frac{q^n}{1 + q^n} \cos 2nx. \quad . \quad . \quad . \quad (34)$$

SUMMARY.

If $$f(u+2np)=f(u),$$

and $$\phi(u+it)=f(u);$$

then $$\frac{\pi}{p}f\left(\frac{nx}{\pi}\right)=A+\Sigma(a_n\cos nx+b_n\sin nx),$$

$$\frac{\pi}{p}\phi\left(\frac{px}{\pi}\right)=A'+\psi(x)+\Sigma(a'_n\cos nx+b'_n\sin nx),$$

when $\psi(x)$ is such a function of X that $\psi(x+iy)=\Sigma(\lambda_n+i\mu_n)e^{nxi}e^{-ny}$.

Change $\frac{px}{\pi}$ into $\frac{px}{\pi}+it$ in (2), and put $e^{-\frac{t\pi}{p}}=q$; we get

$$\frac{\pi}{p}f\left(\frac{px}{\pi}\right)=A'+\Sigma(\lambda_n+i\mu_n)q^ne^{nxi}+\tfrac{1}{2}\Sigma\left[a'_n(q^ne^{nxi}+q^{-n}e^{-nxi})-b'_ni(q^ne^{nxi}-q^{-n}e^{-nxi})\right]$$

$$=A'+\tfrac{1}{2}\Sigma\left[\{\lambda_n+a'_n)\,q^ne^{nxi}+a'_nq^{-n}e^{-nxi}\}+i\{(2\mu_n-b'_n)q^ne^{nxi}+b'_nq^{-n}e^{-nxi}\}\right];$$

therefore $a_n=(2\lambda_n+a'_n)\,q^n=a'_nq^{-n}$; therefore $a'_n=\frac{2\lambda_nq^{2n}}{1-q^{2n}}$, $a_n=\frac{2\lambda_nq^n}{1-q^{2n}}$,

$b_n=(b'_n-2\mu_n)q^n=b'_nq^{-n}$; therefore $b'_n=-\frac{2\mu_nq^{2n}}{1-q^{2n}}$, $b_n=-\frac{2\mu_nq^n}{1-q^{2n}}$;

therefore $$\frac{\pi}{p}f\left(\frac{px}{\pi}\right)=A+\Sigma\frac{2q^n}{1-q^{2n}}(\lambda_n\cos nx-\mu_n\sin nx).$$

XVI.—*On a Geometrical Transformation of the Fourth Order, in Space of Three Dimensions, the Inverse Transformation being of the Sixth Order.*

By L. Cremona, LL.D. Edinb.; F.R.S.; *Professor of Higher Mathematics in the University of Rome.*

[Read, April 28th, 1884.]

The subject of this short Memoir is that of Geometrical Rational Transformation in Space of Three Dimensions. When the points of a space S have a (1, 1) correspondence with those of another space s, in such a manner that the planes and the (right) lines of s correspond to surfaces F of m^{th} order, and to curves C of the n^{th} order in the former space S, I say that the transformation of s into S is of the m^{th} degree, and that the inverse transformation (of S into s) is of the n^{th} degree. In fact the planes and the (right) lines of S correspond to surfaces ϕ of the n^{th} order, and to curves k of the m^{th} order, in the space s. The surfaces F (or ϕ) are homaloid (unicursal after Cayley and Salmon), and form what I name a *homaloidic* system; that is to say, a single surface will pass through three *arbitrary* points, and three surfaces will have a single common point (if not an infinite number), which is not common to the whole system. Two surfaces have, in common, a unicursal curve C (or k).

Generally there are (*fundamental*) points common to all the surfaces F (or ϕ); if their number is an infinite one, they form (*fundamental*) curves,

which can be single or multiple for the surfaces of the system. The points on fundamental curves of each system are *exceptional* ones, with respect to the transformation: they do not correspond to *single* points of the other space, but rather to curves, whose loci are surfaces forming the *Jacobiana* of the second system. Of the two homaloidic systems, if one is known, the other is determined too. And if the correspondence is given between the points of a single homaloid surface and those of a plane, my method finds out all the homaloidic systems to which the given surface can belong.

I will explain the method by an example, which may be considered as possessing some interest in itself. Let us start from a Nöther's surface F of the 4th order, whose only singularity is a double point O with a single tangent plane Ω, which meets the surface in four (right) lines passing through O. This surface may be represented on a plane f in such a manner that the images of its plane sections may be sextic curves a^2b, having seven double points $a_1, a_2, \ldots a_7$, and four single points b_1, b_2, b_3, b_4 common: all these eleven points being ranged in a single cubic curve ab, which is the image of the singular point O.*

Any other surface F', having the same singularity as F (the same double point O, and the same singular tangent plane Ω), will intersect F in a curve of the 16th order, whose image on the plane f is a curve a^4 of the 12th order, passing four times through each of the seven points a.

In several ways the curve of the 12th order can break up into others of lower degree: I assume a breaking up into a right line and a curve a^4 of the 11th order. Supposing this latter as fixed or given, and the former as variable on the plane f, we shall have the images of ∞^2 unicursal curves C of the 6th order, in which F is cut by ∞^3 surfaces F' passing (like F) through a common curve Γ of the 10th order, whose deficiency is 3. By consideration of images in f, we see that O is a treble point for the curves C, and a fivefold one on Γ; and that every C meets Γ in eleven points.

* See a Paper of mine in the *Collectanea mathematica in memoriam D. Chelini.*

Thus we have got a homaloidic system of surfaces F, F', ... to which the given Nöther's surface belongs. Consequently there exists a (1, 1) correspondence between the points, the planes f and the lines c of a space s, and the points, the quartic surfaces F, and the sextic curves C of the space S, from which we started. Then the planes Φ and the lines K of S will correspond to surfaces ϕ of the 6th order and to curves k of the 4th order; for, the intersections of a ϕ with a line, or of a k with a plane, in s, must correspond to the intersections of a plane Φ with a sextic curve C, or of a line K with a quartic surface F in S.

Besides the variable intersection k of the 4th order, the surfaces ϕ of the homaloidic system in s must have in common some fixed curves equivalent to one of the order $(6^2 - 4 =) 32$. To find them out, let us remember that a point of a r-ple curve common to the ϕ's corresponds to a unicursal curve of the r^{th} order lying on the Jacobiana of the F's, and that the intersections of the r-ple curve with a plane f correspond to an equal number of curves of the r^{th} order common to an F and to the Jacobiana.

The curves of F corresponding to single points in f are seven conics and four lines whose images are the seven points a and the four points b; therefore the surfaces ϕ of the homaloidic system in s will have in common a double curve δ of the 7th order, and a simple curve ω of the 4th order. The Jacobiana of the F's is then composed of two parts: 1°. the surface Δ of the 11th order, which is the locus of the conics touching in O the plane Ω and meeting the curve Γ four times; 2°. the plane Ω as being the locus of lines through O. The curve Γ is a treble one on Δ.

An arbitrary plane Φ in S corresponds to a sextic surface ϕ in s; but, if Φ is a plane Ψ passing through O, which is a treble point on any sextic curve C, the correspondent ϕ will break into two cubic surfaces; of which the one, ψ_0, is fixed and answers to the fundamental point O; whereas the other, ψ, is variable in a linear two-fold system (*réseau*) including ψ_0. The cubic ψ coincides with ψ_0 when the plane Ψ falls on Ω. As on every ϕ, δ is a double curve of the 7th order and ω a simple one of the 4th order, we see at once that all the cubic surfaces ψ pass through δ, but only ψ_0 passes through ω too.

Reciprocally all cubic surfaces (ψ) through the fundamental curve δ of the 7th order correspond to planes (Ψ) through O: because the partial Jacobiana Δ must then break off from the surface of the order $(3 \cdot 4 =) 12$ corresponding (in S) to any cubic surface (in s).

Let us consider the representation of the points of any ψ on those of its correspondent plane Ψ. This plane meets Γ in five points, besides O; therefore it will cut the F's in curves of the 4th order, of which $4^2 - 5 - 3 = 8$ common points are coinciding with O. Consequently, the images of plane sections of ψ on Ψ are quartic curves (with two consecutive double points on O and Ω) having eight common intersections gathered up in O and five other common (simple) points. This threefold system of quartics contains a twofold one of such curves having a treble point at O (with two coinciding tangent lines on Ω); whence it follows that the cubic surfaces ψ possess a common double point o.

Two cubic surfaces ψ meet, further, in a conic corresponding to a line through O. Therefore all the analogous conics are passing through o, and this point is a treble one on the curve δ, whose deficiency is 3. This can be proved by projection of one ψ from the double point o on a plane π; a representation which can also result from the foregoing one of ψ on Ψ, combined with quadric transformation. The images of plane sections are then cubic curves meeting in six fixed points p the conic which represents the double point o; and the image of the intersection of our surface with any other cubic surface will be a quintic p. A conic passing through o is represented by a line drawn through one of the points p; then, if the conic is common to the two cubic surfaces, the image of their further intersection δ will be a quartic passing through the five remaining points p; whence we recognize at once the deficiency of δ and the number of its branches through o. Besides, we see that the conic meets δ in four points in addition to o.

Any plane Φ (in S) intersects the F's in a threefold system of quartic curves passing through ten common points G, which are the tracks of Γ; these curves are then the images of plane sections of a surface ϕ, when this is put in correspondence with the plane Φ. Looking up to the intersection

of this plane with the Jacobiana of the F's, we find that the fundamental curves δ, ω have, as their images on Φ, a curve $\nabla \equiv G^3$ of the 11th order and a right line, whence it follows that δ and ω meet in eleven points. Any one of the conics, whose locus is the partial Jacobiana Δ, pierces the plane Φ in two *conjugate* points of ∇ answering to one point of the double fundamental curve δ. Every quartic G meets with ∇ only in pairs of conjugate points.

From this representation on Φ, we infer that every sextic surface ϕ contains ten right lines, which are lines through three points of the double curve δ. The locus of such lines is a partial Jacobiana for the ϕ's corresponding to Γ: its degree is 11; for, in the space S, every curve C meets Γ in 11 points. The fundamental point O is a treble one for every C, and absorbs nine of the twenty-four linear conditions determining a unicursal twisted sextic curve; therefore, the Jacobiana of the ϕ's is completed by a surface of the third order three times counted: the cubic ψ_0. We see at once that δ is a 4-ple curve on the former partial Jacobiana.

Any two of the ϕ's have as intersection (besides δ and ω) a unicursal quartic curve k, corresponding to a right line in S; every k meets δ in eleven points, and ω in one point, because in S these numbers eleven and one are the orders of the surfaces making up the Jacobiana of the homaloidic system.

Applying to the projection of ψ_0 from o on a plane, it is easy to see that o is a treble point on every surface ϕ.

We saw above that lines K (in S) correspond to quartic curves k meeting ω in one and δ in eleven points; and that lines c (in s) correspond to sextic curves C cutting Γ eleven times and having O as treble point with tangent lines on the plane Ω. But curves k and C will degenerate into curves of lower order when the line K meets Γ or passes through O, or when the line c cuts δ or ω; for, to any point of Γ, ω, δ, corresponds a line or a conic, &c. Thus, for instance, lines cutting Γ three times correspond to chords of δ supported by ω; lines projecting Γ from O correspond to lines projecting δ from o; lines through three points of ω correspond to cubic

(twisted) curves meeting Γ in eleven points; &c. The point o has, as its image in the space S, the three chords of Γ which spring from O.

Our transformation, by which we purposed to give an example of the general method, is now established and completely explained in its chief circumstances.

XVII.—*Catalogue of the Earthquakes having occurred in Great Britain and Ireland during Historical Times; arranged relatively to Localities and Frequency of Occurrence, to serve as a Basis for an Earthquake Map of the Three Kingdoms.* By Joseph P. O'Reilly, C. E., Professor of Mining and Mineralogy, Royal College of Science, Ireland. (Plate XI.)

[Read, April 28, 1884.]

In a Paper read before the Academy, November 14th, 1881, I submitted considerations tending to establish a relation between coast-line directions and certain localities in Europe noted for frequency of earthquakes. The map then exhibited was the first produced showing such a relation between earthquake localities and lines of physical structure, such as coast-lines, main lines of jointing or faulting, mountain chain directions, and boundary lines of geological formations. Its importance and interest lies in the consideration, that as to earthquakes representing the action of hypogenic forces, the localization of these forces enables us to compare the localities and lines of country affected thereby during historical time with those which, during geological time, were the seats of action of similar forces. Earthquakes are frequently followed by changes in the level of the districts affected thereby: consequently, a map which would represent the sum of the earthquake action having taken place, during historical time, in a given country, should enable us to judge of the amount of surface having undergone either depression or elevation, with all the consequences following physically therefrom. Certain parts of the coasts of Great Britain and of France, for instance, are undergoing change in this respect, and there is ground for, and interest in, inquiring how far these changes are to be attributed to earthquake action. Moreover, earthquake action must have been

continuous during all geological time, and been the most potent factor of geological change; consequently a geological map, to be really complete, should, so far as possible, show the distribution of the centres of earthquake action and the surfaces affected thereby. An earthquake map becomes thus the necessary *pendant* of the geological map.

There is certainly a very great difficulty in procuring sufficient and exact data for such a map, and in devising a method of representation which will satisfactorily show the distribution, relative frequency of occurrence, and, if it were possible, the intensity of the various earthquakes recorded. In the Map of Europe submitted to the Academy this was only imperfectly carried out; nevertheless, the results shown were of very distinct bearing and interest, geologically. Since then I have thought that, while the intensity of a shock could with difficulty be represented graphically, yet the locality and relative frequency of occurrence may be sufficiently well represented by gradation of tint, and a map thus formed would bring out new and very interesting geological relations.

For this purpose I have catalogued the earthquakes recorded as having occurred in the three kingdoms, relative to locality and frequency, and having adopted a unit tint for districts and a unit size of mark for localities (towns, cities, villages, &c.), I have mapped the three kingdoms relative to the data furnished by the Catalogue. In the Catalogue I have given the dates of the earthquakes, though unnecessary (except in the special list of the earthquakes which have affected large districts), as it may allow of a relation of simultaneity of shock being established between points at a distance one from the other.

Such a catalogue has not only the advantage of presenting those wonderful phenomena in a more condensed and more useful form than that of a simple chronological narration, wherein each event stands by itself, disconnected and unintelligible, but has also the further very great advantage of serving as a starting-point for the construction of earthquake maps, which I assume to be indispensable for the complete comprehension of geological phenomena. In order to show this to some extent, and without interfering with the clearness of the map, I have traced on that of Great Britain and Ireland (Plate XI.) the coal-fields of these countries, as shown on

Ramsay's Geological Map of the British Isles, thus bringing them into relation with the earthquakes recorded of the districts.

The present Paper contains, therefore, a catalogue of the earthquakes recorded as having occurred in the British Isles up to 1880, and observations thereon, relative to the positions of the points of action of the earthquake forces, and the relations of the coast-line directions, with the localities marked by such action, with the boundaries of the districts of action, and, finally, with the coal-fields, having in view the still debatable question of the origin of coal. I have further added a list of the earthquakes which affected large districts or several places simultaneously, commencing about 1670, when the records appear to assume a certain degree of detail and preciseness. These allow of the examination of the extent and form of surface of the districts affected, and the nature of their boundary of lines. Furthermore, cataloguing these relative to the months of the year in which they occurred, a curve is obtained which shows a singular correspondence with a curve formed in a like manner from a list of colliery explosions of great violence having occurred in Great Britain since 1840, the details of which are given further on. This comparison would so far tend to establish a distinct connexion between earthquake action in these countries and colliery explosions, a relation not yet clearly recognized, and which is at this present moment being elaborately investigated by Professor Milne, in Japan, at the coal mines of Takashima, near Nagasaki (*Nature*, No. 748, vol. xxix., p. 413, February 28, 1884). If this relation can be more generally and more distinctly established, a point would be attained in the question of the origin of coal, of singular importance, both theoretically and practically.

An examination of the map shows at once that, so far as record indicates during historical time, Great Britain has been by far more subject to earthquake action than Ireland; and from this may be inferred the existence of barriers capable of preventing the extension of earthquake action from Great Britain to Ireland, as also the absence, beneath the surface of Ireland, of active foci capable of producing earthquakes in the present geological order of things.

As barriers, may be considered the sea, and more particularly, main

lines of faulting, or marked lines of boundary between distinct geological formations. The differences between the formations on the east coast of Ireland and those on the west of Great Britain are, however, not so marked as to allow of this discontinuity of action being attributed to them solely; and it is presumable, therefore, that between the two islands occur great lines of fracture affecting the general outline of the coast, and which serve as barriers to the extension of earthquake action from one island to the other. I have shown, in two Papers submitted to the Academy,* that the coast-lines from Carnsore Point to Dundalk are represented in direction by the lines of fracture dominating in the rocks about Dublin Bay. One of these, that representing the coast-line between Carnsore Point and Wicklow Head, is clearly represented in direction by a depression in the southern part of the Irish Channel, extending from the Scilly Islands to Bardsey Island, at the northern extremity of Cardigan Bay, and which may reasonably be considered as corresponding to a line or system of lines of faulting having the direction of this depression. This direction, being produced, passes through remarkable points, such as the Isle of Man (in its length as axis); Leadhills, in Scotland; the eastern boundary of the Glasgow coal-field; Perth, and the Shetland Islands, running parallel to them, and corresponding in a marked manner to the general direction of the eastern coasts of these islands, between Sumburgh Head and Unst Island. In Scotland this direction is related, by parallelism, with the east coast between Fifeness and Aberdeen, and with the Banff coast and the extreme north coast between Cape Wrath and Duncansbay Head, by the angle of 70°, as shown on the map. It may be considered therefore as representing, or corresponding to, a series of main lines of jointing capable of acting as barriers to the extension of earthquakes.

That main lines of jointing are now recognized as having intimate relations with earthquake shocks is admitted, and in this respect I may cite one of the conclusions arrived at by Mr. Stevenson, in his remarkable Paper on the earthquake which occurred in the north of Scotland and Ireland, November 20, 1880, and which is as follows:—"That the source of the

* Proc. R. I. Acad., vol. iii., second series, Science, p. 295.

earthquake lay at or near the great fracture of the earth's crust, which runs in a south-west direction from Inverness" (Proc. R. Soc. Ed., No. 109, p. 176).

As to the evident relations between earthquakes and coast-lines, I may point to the south coast of England, as shown on the map. It will be observed that a line which correctly defines the direction of this coast passes through the Scilly Islands, near Penzance, at Falmouth, near Devonport, at Portsmouth and Chichester, quite near Dover, all localities marked by relative frequency of earthquakes, as indicated by the map. This character would correspond to the noted frequency of volcanic action along coast-lines, and so far as earthquake action is connected with volcanic action there is identity of character.

It may be interesting to call attention to the fact that this line makes an angle of 70° with the theoretical great circle, "West coast of Portugal" (parallel to which lines of jointing occur in the neighbourhood of Dublin), and that a line making 70° with the southern coast-line of England on the east represents very correctly the direction of the eastern coast of England, from Yarmouth to Fifeness in Scotland; while a line parallel to this would pass through Rattray Head and Duncansby Head.

A certain relationship may also be observed to exist between the principal coal-fields noted for the frequency of their gas explosions and the neighbouring localities noted for the frequency of their earthquakes. This is notable for Lancashire and South Wales, as may be seen from the map. A point of great interest in this respect is the possible relation between the continuation of the coal-measures to the south of London and the system of jointing existing in this part of Great Britain. In discussing this most important question, Mr. Prestwich came to the conclusion that the probable position of the axis of "the great underground coal-trough is likely to be on a line passing through North Wilts, Oxfordshire, thence across Hertfordshire, South Essex, the south-east extremity of Kent, onwards towards Calais, near to which place it is thrown out by the rise of the underlying rocks, but resumes again at Théronanne; or, in case of the anticlinal axis taking a more southern course, we should look for the coal basin or coal basins along a line passing from Radstock through the Vale of

Pewsey, and thence along the North Downs to Folkestone, and near to Calais. The discovery of upper Devonian strata both at Turnford and at Tottenham Court Road, in both cases dipping at high angles, lends not a little support to the view that a trough of carboniferous strata may exist between these two localities." (*Nature*, vol. xxv., p. 361: Professor Judd on the "Search for Coal under London.")

This direction may be correctly represented by a line passing through Dover, and making an angle of 70° with the theoretical great circle, "West coast of Morocco," marked on the map.

If frequency of earthquake were proved to be in relation with the existence of coal in a given locality, and also with the existence of great lines of fracture, then the line, or great circle, which extends along the south-west coast of Wales, which cuts the south coast of England near Bangor, and cuts the coast of France at the northern point of the entrance of the Somme River, as shown on the map, and along which earthquake occurs with marked frequency, that line might furnish some indication as to the locality of the presumed coal-fields.

Of course it would be necessary that a map, such as that submitted, should be constructed for Europe, and examination be made of the there existing coal-fields, in order that conclusions be usefully drawn therefrom. Such a map must have for basis a catalogue of the earthquakes of Europe similar to this present one of Great Britain and Ireland. On this catalogue I am at present engaged, and hope to be able to submit to the Academy a map based upon it.

List of Earthquakes, *having affected Districts of some extent in the* Three Kingdoms *during Historical Times, according to date, with details.*

1426. September 29, Throughout the whole of Great Britain.

1574. February 26, . York, Worcester, Gloucester, Bristol, Hereford, and the neighbouring counties.

1580. April 6, . . Throughout England, especially at London, Dover, and whole of Kent; also in France at Boulogne, Calais, Paris, &c. In Belgium at Brussels, Malines, Cologne, &c. In Zealand and Holland. Most violent in England.

1661.	January 18,	. Oxford, Belckington, Stanton, Coventry, Brill, &c., in England; also, at the same time, in the district of Eisenthores, Temeswar, Hungary.
1671.	September,	. Coasts of the English Channel and German Ocean, St. Malo, Havre, Calais, Dunkirk, Antwerp.
1680.	January,	. Chedsey, Somersetshire, and the country for some miles round.
1683.	September 28,	Oxford and neighbourhood, Burford, Wattlington, and other places in Berkshire; appears to have extended so far as Burford in the north, Long Handbourg in the north-west, Brompton in the west, Abingdon in the south, and the Thames in the east; area about seventy square miles.
,,	October 9,	. Oxford and so far north as Derbyshire "and the country where the coal mines are"; very feeble at Oxford, but violent further north.
1704.	January 8,	. Hull, Beverly, South Dalton; most violent in the neighbourhood of Lincoln; feeble at Selby and Navesby.
1731.	October 19,	. Aynho, in Northamptonshire, and in the neighbourhood of Bloxham (four miles south-west), Adderbury, Croughton (one mile east), and Charlton (one mile north).
1732.	November 29,	Stronthran, in Argyleshire, and all along the west coast of Scotland, though to no great breadth.
1734.	November 5,	. In Sussex, especially at Havant, Arundel, Goring, Farning, Shoreham, Goodwood, &c.; also felt at Portsmouth and Chichester.
1748.	July 12, .	. Taunton in Somersetshire, and the country from the English Channel to the Severn, and extending about the same distance east and west, being felt at the same time at Exeter and Crookerne.
1750.	February 19,	. London and the country for seven miles round.
,,	March 29,	. Portsmouth, Bridport, Southampton, Bath, Northaer, Gubbins, Hatfield, Hackney near London; also Jersey and Guernsey.
,,	April 13,	. Extended from Lancaster to Wrexham, in the direction north to south; and from Flintshire to Stockport and Altringham in that of east to west; rather violent at Chester and Manchester.
,,	May 15,	. Wimborne, Dorsetshire, and the country for twenty miles round.

1750. October 11, . In the counties of Northampton, Leicester, Suffolk, Nottingham, Rutland, and Lincoln, extending west to east from Warwick to Bury in Suffolk, and north to south from Lincoln to Northampton.

1756. February 18, . Very extended shocks in the Alps; some parts of France and Germany; in the Netherlands; and in England, London, Dover, Deal, Margate, Canterbury; and even Glasgow.

1757. July 15, . Scilly Islands and Cornwall; most violent in the island of St. Mary, and extending with diminished intensity to Penzance, Marizion, St. Ives, Tohidy, Redruth, St. Coulomb, Bodmin to Camelford, ninety English miles from the Scilly Islands; at Losturthial, Liskeard, and even at Loo and Plymouth the shocks slightly felt.

1761. March 31, . Second great Lisbon earthquake felt at Cork.

,, June 9, . . Sherbourne, Shaftbury, and the country for seventeen miles round.

1776. November 27, Canterbury, Sandwich, Ashford, Dover, and all the coast of Kent.

1777. September 14, Manchester; also, with less violence, at Lancaster, Liverpool, Birmingham, Derby, Chester, York, Gainsborough; extended over an area of 130 to 140 miles in diameter.

1780. August 29, . Wales: Hafodunos, Downing, Isle of Anglesea, Carnarvon, Isle of Clwyd, Denbigh, Holywell, Flint, Conway, Beaumaris, Llanwrst, and Holyhead.

1786. June 16, . Whitehaven, the south of Scotland, Isle of Man, Dublin.

,, August 12, . Whitehaven, Lancaster, Cartmill, Newcastle, Glasgow, Isle of Man, Dublin.

1792. March 1, . Bedford, Leicester, Lincoln, Nottingham, and other counties; simultaneously at Stamford and Doncaster.

1795. November 18, In England, extending from Leeds to Bristol, and from Norwich to Liverpool (vibrations from south-west to north-east).

1801. September 7, . Edinburgh, Glasgow, Perth, Callender, Crieff, Stirling, and almost the whole of Scotland: the centre appeared to be in Comrie, in Perthshire.

1816. March 17, . Inverness and the country for one hundred miles round, including Aberdeen, Perth, and other places in the north of Scotland, the centre of disturbance being apparently in Inverness-shire.

1818. April 30, . Extending from one side of Lincolnshire to the other, and across Holderness, in Yorkshire.

1832. December 31, Swansea, Neath, Llandovery, Caermarthen, and other places in South Wales; and at Castlebridge, Co. Wexford.

1834. January 23, . Chichester and Longfleet, near Poole, in Dorsetshire; felt also at Lipkook, Farnhurst, Petworth, Palborough; Bognor, Portsmouth, and Gosport. The centre of intensity supposed to be a few miles north of Chichester.

,, August 27, . Along the coast of Hampshire, at Portsmouth, Gosport, Southampton, Chichester.

1837. December 8, . Stamford, in Lincolnshire, and the county for twenty miles round.

1838. March 17, . Shrewsbury, and the neighbourhood extending about nine miles from that town, chiefly in a south-westerly direction; felt in the coal pits.

1839. October 23, . Felt throughout two-thirds of Scotland; the southern limit nearly coincided with a line drawn from the Solway to the mouth of the Tweed, and the northern limit as nearly coincided with the course of the Caledonian Canal. The intensity greatest at Comrie. The longer diameter of equal intensity north-east to south-west, or parallel to the Grampian Hills.

1843. March 10, . All the country to the north-east of Manchester; especially violent in the chain of hills between Yorkshire and Lancashire.

,, March 17, . Simultaneously in the counties of Lancashire, Cumberland, Dumfries, Isle of Man, Belfast, and even in Jersey and Guernsey. Did not reach the south and south-east of England. The focus between Yorkshire and Lancashire.

1846. November 24, Perth; felt in all the north; very violent along the Grampian Hills, at Inverness, and in district of Aird.

1852. April 5, . . Bristol; seems to have followed an axis of shock, nearly north and south, on which are found the Mendip Hills, Wells, Chedder, Pensford, and Dundry, in Somersetshire; Bristol, Westbury-on-Trym, and Hembourg, in Gloucestershire. The centre of shock was apparently at Chedder.

1852. November 9, . Liverpool and environs, Bangor and Holyhead, Manchester, Fleetwood, Congleton, and all Wales, Dublin, Kingstown, Bray, Kilruddery, Dalkey, Glenageary, Howth, Clontarf, Glasnevin. The direction apparently north and south.

1853. April 1, . . Normandy; extended on the west to Jersey and Guernsey; the direction north-east to south-west. Also felt at Plymouth, Southampton, Portsmouth, Brighton, Dorset, Hampshire, and Weymouth. The area shaken estimated at 20,000 square miles.

1858. November 11, Mount St. Michael, Penzance Bay. At 7.15, A.M., four hours previous to the shock at Mount St. Michael, a shock was felt at Lisbon, affecting a part of Spain and Portugal. Remarkable that after the great earthquakes of Lisbon of 1755 and 1761 shocks were felt at Mount St. Michael.

.. September 28, At Druits, one mile north-west of Ashburton; Dartmoor and environs, Chagford on the granite; Drewsteinyton on the carboniferous and near granite. The area shaken forms a zone, twenty-one miles long, from east to west; and about eight miles broad, from north to south.

1863. October 6, . Shock affecting the counties of the centre of England, and all Wales; according to Mr. Lowe it extended north to Doncaster, Huddersfield, and Clitheroe; east to Market Raden, Peterborough, and Bedford; south to London, Dorchester, and Plymouth; west to Dublin and Wexford. Also felt at Lancaster, Ulverton, Harrowgate, Malton, Scarborough, Bury St. Edmund, Brighton, and Isle of Wight. A line from Stafford to Cardiff would pass through the places the most strongly shaken.

In the History of the Earthquake of 1863, October 6, by E. J. Lowe, he marks on his map an oval, running south-west to north-east, as of maximum intensity, in which are found Hereford, Ross, Brecon, Monmouth, and Newport. It was at Galway, twelve miles from Ross, same distance from Hereford and Abergavenny that the shock seemed to have been most violent.

1864. September 26, Manchester and centre of England; motion north-east to south-west; felt at Rochdale, Hebdenbridge, Broughton, Pendlebury, Salford, Skipton, Silsden, and other localities of the county of York.

1868. January 4, . Valley of Parret, between Langport and Stoke-sub-Hamilton (Somerset).

1868. October 24, . Newtown, some miles from Mallow, Co. Cork; felt also at different places between Mallow and Kanturk.

871. March 17, . Several shocks in the northern counties of England. The surface shaken, comprehended in a circle having for centre a point about two miles east of Sedbergh, Dumfries, in Scotland, and Doncaster, in Yorkshire, were the north-west and south-east limits. The circumference passes by the Humber, Doncaster, Manchester, Salford, Roby, Hayton, Seaforth, Southport, Blackpool, and west of Ulverstone, Lake Comeston, and Dumfries.

An inner circle of greater shock, passing by Scarborough, York, New Malton, Leeds, Bradford, Preston, Longrade, Kendal, Penrith, Carlisle, Newcastle, and Sunderland, to Wensleydale and Swaldale, Yorkshire.

1874. November 16, Carnarvonshire and Anglesea, in the morning. The same morning, 6 o'clock, a very strong shock at Constantinople, Smyrna, and other parts of Asia Minor, Anatolia, and Rhodes.

1880. November 28, Earthquake, extending from Bull of Lewis in the Hebrides to Armagh in Ireland, and from Barrahead in the Hebrides to Blair Athol, over a surface of at least 19,000 square geographical miles, though to what additional extent it may have been propagated into the Atlantic it is impossible to say.

The centre presumed to have been at a point lying south south-west of Phladda lighthouse, and north of M'Arthur's Head lighthouse.

The source of the earthquake lay at or near the great fracture which runs in a south-westerly direction from Inverness, and the shock was probably due to a rupture of the crust of the earth at this very distinct line of fracture. ("Earthquake of 28th November, 1088, in Scotland and Ireland," by Ch. Alex. Stevenson, *Proceedings*, R. Soc. Edinb., No. 109 p. 176.)

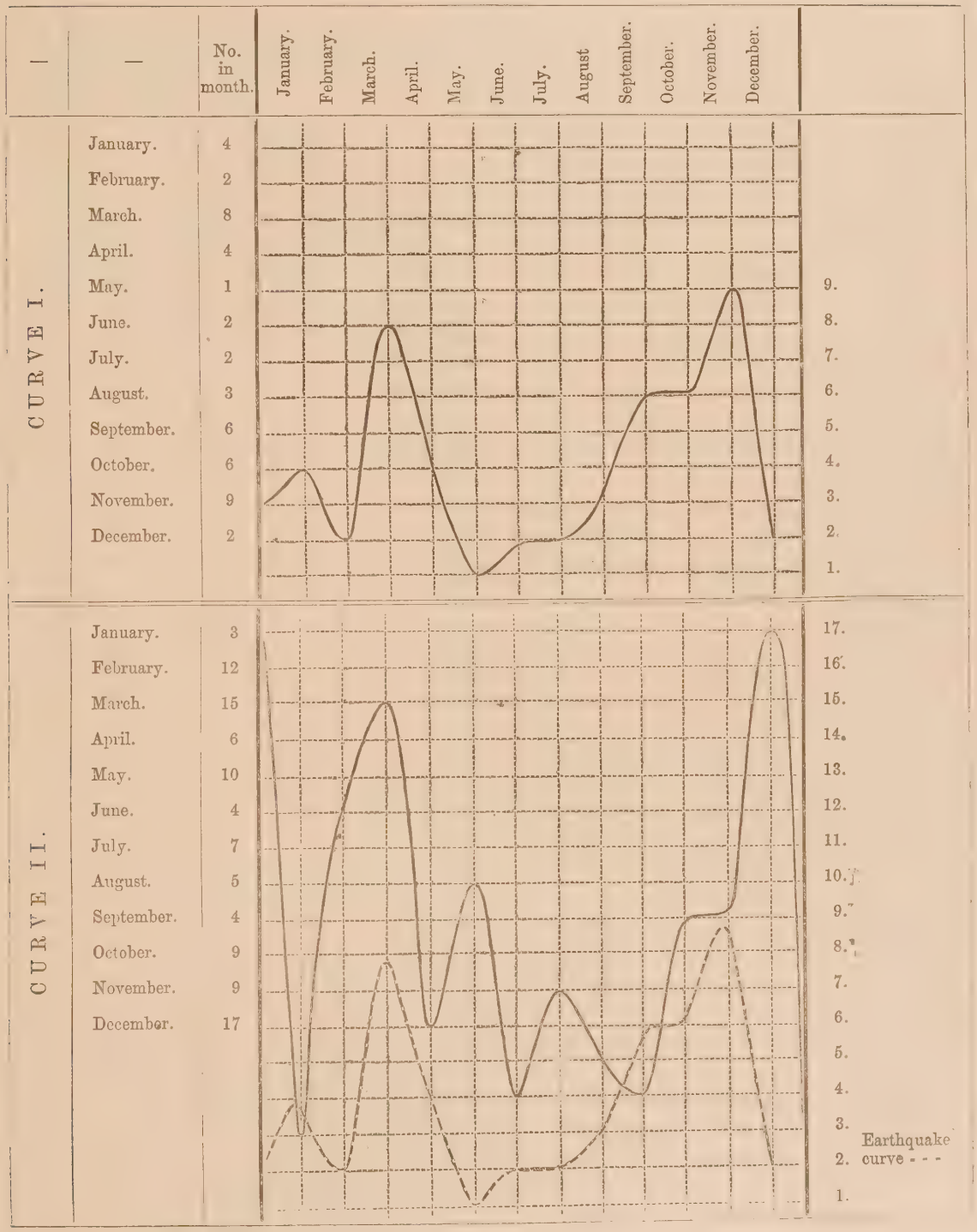
CURVE I.

Represents the comparative frequency of the earthquakes mentioned in the foregoing Table relative to the months of occurrence and shows two maxima, one in March, the other in November; and two minima, one in May, the other in December.

CURVE II.

Is based on the return, "Explosions de Grisou, survenues en Angleterre, depuis 1850, dans lesquelles ont peri six personnes, au moins" (Pernolet et Aguillon : *Exploitation et Réglementation des Mines à Grisou en Belgique, en Angleterre, et en Allemagne, Rapport de Mission, Angleterre,* Annexe, No. vii., p. 312), and shows the months of maxima and minima of explosions comparatively with those of earthquakes in Great Britain.

The comparison of these curves is of very great interest, showing, as they do, a very marked concordance as regards the months of maxima and minima, with the interesting difference, that whereas, the maxima of earthquakes being in November, that of colliery explosions is in December, which may be interpreted as implying, that the explosion being considered as the *consequence* of a previous earthquake movement, the period of the explosion should follow that of the earthquake.


No. in month.
January.
February.
March.
April.
May.
June.
July.
August
September.
October.
November.
December.
CURVE I.
January. 4
February. 2
March. 8
April. 4
May. 1
June. 2
July. 2
August. 3
September. 6
October. 6
November. 9
December. 2
9.
8.
7.
6.
5.
4.
3.
2.
1.
CURVE II.
January. 3
February. 12
March. 15
April. 6
May. 10
June. 4
July. 7
August. 5
September. 4
October. 9
November. 9
December. 17
17.
16.
15.
14.
13.
12.
11.
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
Earthquake curve - - -

Detailed Catalogue of Districts and Counties *marked by the occurrence of Earthquakes during Historical Times in Great Britain and Ireland, taken from the General Catalogue.*

Places.	No. of Shocks.	Years.
All England,	29	974, 1043, 1076, ——, ——, ——, 1081, ——, 1085, 1089, 1090, 1099, 1117, 1119, 1153 (very violent), 1185, 1186, 1199, 1246, 1274, 1275, 1284, 1382, 1385, 1426, 1580, 1661, 1692, ——.
North of England,	2	1871, ——.
Centre of England,	2	1863, 1864.
West of England,	1	1867.
Anglesea Island,	5	1780, 1782, 1827, 1842, 1874.
Berkshire,	1	1683.
Carnarvonshire,	1	1874.
Channel (English),	1	1671.
Coast of Kent,	1	1776.
Cornwall,	3	1756, 1757, 1859.
Derbyshire,	1	1683.
Dorsetshire,	2	1750, 1853.
Durham,	2	1179, 1816.
Dorsetshire Coast,	1	1839.
Flintshire,	1	1750.
Frith of Clyde,	1	1871.
Glamorganshire,	2	1765, 1868.
Gloucestershire,	1	1812.
Grampian Hills,	2	1819, 1846.
Guernsey Island,	4	1750, 1761, 1843, ——.
Hampshire Coast,	1	1834.
Herefordshire,	1	1755.
Hertfordshire,	1	1755.
Ireland (West of),	1	1756.
Innishowen (Barony of),	1	1841.
Jersey Island,	6	1750, 1790, 1804, 1843, —— 1868 1872.
Kent,	3	1246, 1580, 1727.
Lancashire,	6	1817, 1839, 1843, 1869 ——.
Leicestershire,	2	1750, 1776.

Places.	No. of Shocks.	Years.
Man (Isle of),	4	1786, ——, 1788, 1843.
Monmouthshire,	2	1839, 1865.
Mull (Isle of)	2	1839, 1865.
Netherlands Coast and English Coast	1	1134.
Norfolkshire,	3	1165, 1201, 1869.
Northamptonshire,	2	1731, 1750.
Nottinghamshire,	1	1750.
Oxfordshire,	1	1812.
Scotland,	1	1872.
,, (north of),	3	1846, 1869. ——.
,, (south of),	1	1780.
,, (west of),	1	1873.
,, (two-thirds of),	1	1839.
Shropshire,	2	1712, 1836.
Somersetshire,	4	1199, 1680, 1752, 1868.
Staffordshire,	1	1678.
Suffolk,	4	1165, 1201, 1750, 1869.
Surrey,	1	1750.
Sussex,	2	1734, 1861.
Wales (all),	5	1274, 1780, 1852, 1868, 1869.
,, (northern),	3	1780, 1827, 1842.
Wight (Isle of),	2	1750, 1863.
Wiltshire,	1	1764.
Westmoreland,	1	1817.
Worcestershire,	1	1868.
Yorkshire,	3	1738, 1817, 1869.

Summaries of Names of Localities *mentioned in the General Catalogue, according to order of frequency of Occurrence of Earthquakes thereat.*

No. of Occurrences.	Localities.
2	Aberdeen, Abington, Adderbury, Ardvoirlich, Belfast, Bognor, Broughton, Burford, Callander, Camelford, Clwyd Vale, Clitheroe, Dalton, Dorsetshire, Dumbarton, Dores, Dumfries, Durham County, Edinburgh, Ely, North of England, Furness, Glamorganshire, Glengarry (Scotland), Gloucester, Grampian Hills, Greenock, Havant, Kingsdown, Kintail, Leicestershire, Liphook, Lough Erne (Scotland), Middleton, Monmouthshire, Northampton, Northamptonshire, Peterborough, Preston, Ramsgate, Ripon, Scarborough, Sherbourne, Shropshire, Strathearn, Stirling, W. Sussex, St. Ives, Taunton, Lyrndrum, Urquart, Wells, Weston-super-Mare, Wexford, Wight (Isle of), Wolverhampton.
3	Ashford (Kent), Bangor, Bedford, Bury, Caermarthen, Canterbury, Cardiff, Chedder, Chester, Cornwall, Dartmoor, Derby, Downing, Fortwilliam, Gosport, Hereford, Holyhead, Kendal, Kent, Leadhills, Leeds, Leicester, Loughgilpead, Newcastle, Norfolk County, Oban, Oxford, Sandwich, Scilly Islands, Shaftesbury, Shrewsbury, Southampton, Swansea, Wales (the north of), Wenlock, Yorkshire.
4	Bath, Brighton, Cork, Deal, Doncaster, Guernsey, Liskeard, Isle of Man, Newport, Redruth, Southampton, Suffolkshire, Whitehaven.
5	Anglesea Island, Dover, Dublin, Falmouth, Lincoln, Liverpool, Stamfor , Worcester, York.
6	Crieff, Lancashire, Nottingham, Penzance, Perth, Plymouth.
7	Bristol, Lancaster, Jersey Island.
8	Inverness, Portsmouth.
9	Manchester.
10	Chichester.
13	London.
29	All England.
259	Comrie.

General Catalogue of Localities *affected by Earthquakes in Great Britain and Ireland during Historical Times, arranged alphabetically, and giving dates of occurrence.*

[For details reference should be made to Mallet's Catalogue down to 1842; for the subsequent years Perrey's Catalogue down to about 1870, and for more recent dates the scientific journals, more particularly *Nature*, or Fuch's Catalogues in Tschermak's *Mineralogische Mittheilungen.*]

Places.	No. of Occurrences in excess of one.	Years.
Aberbarden, near Hereford,	—	1853.
Aberdeen,	2	1608, 1816.
Abbeydore,	—	1853.
Abington,	2	1683, 1771.
Accrington,	—	1869.
Adderbury,	2	1731, 1838.
Aghadoe, Co. Cork,	—	1820.
Albans (St.),	—	1250.
Aldwick,	—	1824.
Almwork,	—	1782.
Altringham,	—	1750.
Amalree (Scotland),	—	1819.
Anglesea Island,	5	1780, 1782, 1827, 1842, 1874.
Apthorpe,	—	1844.
Ardvoirlich (Scotland),	2	1826, 1831.
Argyle, coast of,	—	1871.
Arlington,	—	1179.
Armagh,	—	1880.
Armside Village,	—	1789.
Armitage,	—	1583.
Armley,	—	1871.
Arran Island (Scotland),	—	1826.
Arundel,	—	1734.
Ashbury,	—	1771.
Ashford (Kent),	3	1580, 1776, 1814.
Ashton,	—	1871.
Ashton-on-Ribble,	—	1871.

Places.	No. of Occurrences in excess of one.	Years.
Aspath (St.),	—	1782.
Aspatria (near Carlisle),	—	1871.
Avestry (Shropshire),	—	1863.
Ayhno,	—	1731.
Ayr,	—	1880.
Ballahalish,	—	1880.
Ballymoe (near Tuam, Co. Galway),	—	1756.
Ballinloan (Glentyon, Scotland),	—	1818.
Bambridge,	—	1871.
Banbury,	—	1731.
Bangor,	3	1782, 1818, 1852.
Bardsey Island,	—	1831.
Barnage (Staffordshire),	—	1852.
Barnmouth Merionethshire),	—	1820.
Barnstaple,	—	1789.
Barra,	—	1880.
Barrahead,	—	1880.
Bath,	4	1248, 1750, 1775, 1868.
Beaumaris,	—	1780.
Beeston (near Nottingham),	—	1865, ——.
Becles Parish,	—	1657.
Bedford,	3	1690, 1792, 1863.
Belckington,	—	1666.
Belfast,	2	1843, 1880.
Berkshire,	—	1683,
Betley,	—	1863.
Beverley,	—	1704.
Birmingham,	—	1777.
Blair-Athol,	—	1880.
Bishopthorpe,	—	1754,
Blackburn,	—	1869.
Blackmore,	—	1583.
Blackpool,	—	1835.
Bleanavon Mountains,	—	1868.
Bloxham,	—	1731,
Bodman,	—	1757.
Bognor,	2	1824, 1834.

Places.	No. of Occurrences in excess of one.	Years.
Bordham,	—	1833.
Bosely,	—	1712.
Bray (Co. Dublin),	—	1852.
Bridgewater,	—	1839.
Bridport,	—	1750.
Bridstone (near Campsea, Scotland),	—	1845.
Brighton,	4	1553, 1859, 1868, 1865.
Brill,	2	1666, 1683.
Bristol,	7	1574, 1775, 1795, 1839, 1852, 1868 (and environs), 1752.
Brodick Castle,	—	1880.
Bromley,	—	1750.
Broughton,	2	1864, 1869.
Brosley (Shropshire),	—	1868.
Bulles,	—	1860.
Burford,	2	1683, 1731.
Burton-on-Trent,	—	1864.
Butt of Lewis,	—	1880.
Bury,	3	1750, 1869, ——.
Bury St. Edmunds,	—	1863.
Bytown (Herefordshire),	—	1768.
Caernbaon,	—	1880.
Caermarthen,	3	1801, 1832, 1841.
Callander,	2	1801, 1880.
Callington (Cornwall),	—	1860.
Camelford,	—	1757, 1857.
Cambourne,	—	1842.
Campsie (Scotland),	—	1845.
Canterbury,	3	1691, 1756, 1776.
Campletown,	—	1880.
Cardiff,	3	1839, 1865, 1868.
Cargen (Dumfriesshire),	—	1865.
Carlisle,	—	1871.
Carnarvonshire,	—	1874.
Carnarvon,	—	1780.
Cartmill,	—	1786.
Castlebridge (Co. Wexford),	—	1832.

Places.	No. of Occurrences in excess of one.	Years.
Caversham,	—	1755.
Channel (English),	—	1671.
Chagford,	—	1858.
Charnwood Forest,	—	1838.
Chedder,	3	1852, ——, ——.
Chedsey,	—	1680.
Chelsea,	—	1750.
Chester,	3	1750, 1777, 1800.
Cherston Bishop (Dartmoor),	—	1858.
Chesnut,	—	1750.
Chichester,	10	1638, 1734, 1824, 1833, 1834, ——, ——, ——. ——, 1835.
Chotham,	—	1852.
Chulford (near Stroud),	—	1865.
Clatheck (two miles east of Comrie),		1843.
Cliffe,	—	1844.
Clifford (Herefordshire),	—	1863.
Clifton,	—	1852.
Clitheroe,	2	1835, 1863.
Clontarf (Dublin),	—	1852.
Clwyd Vale,	2	1780, 1805.
Congleton,	—	1852.
Compton,	—	1868.
Colonsay House,	—	1880.
Colebrook Date,	—	1783.
Collywestern,	—	1844.
Comrie,	259	. . . . , 1789, ——, ——, ——, 1790, 1792, 1795, 1799, ——, 1801, 1818, ——, 1820, 1821, ——, 1824, 1828 : 1839 (Oct. 25 shocks, Nov. 20 sh., Dec. 19 sh.) : 1840 (Jan. 14 sh., March 9 sh., April 2 shs., July 5 shs.. Aug. 2 shs., Sept. 3 shs., Octr. 3 shs., Nov. 4 shs., Dec. 6 shs.) : 1841 (Jan. 3 sh., Feb. 3 sh. March 5 sh., April 7 sh., May 7 sh., June 1 sh., July 6 sh., Aug. 4 sh., Sept. 8 sh., Octr. 2 sh., Nov. 7 sh., Dec. 3 sh.) : 1842 (March 1 sh., April 1 sh., June 3 sh., July 2 sh., Aug.

Places.	No. of Occurrences in excess of one.	Years.
		1 sh., Sept. 3 sh., Nov. 2 sh., Dec. 2 sh.): 1843 (March 1 sh., May 2 sh., June 1 sh., July 1 sh., Aug. 1 sh., Sept. 2 sh., Nov. 3 sh.): 1844 (Jan. 4 sh., Feb. 2 sh., March 2 sh., April 1 sh., May 3 sh., July 2 sh., Sept. 2 sh., Octr. 3 sh.): 1845 (May 1 sh., Aug. 1 sh., Sept. 1 sh., Octr. 1 sh., Nov. 1 sh.): 1846 (Feb. 2 sh., March 1 sh.): 1847 (Jan. 2 sh., Feb. 2 sh., May 2 sh., Oct. 2 sh.): 1848 (Jan. 1 sh., May 1 sh., July 1 sh.): 1851 (Feb. 1 sh., May 1 sh.): 1857 (Octr. 1 sh.): 1864 (July 2 sh.): 1867 (Aug., reached Greenloning, 12 miles west of Comrie): 1869 (July, and surrounding villages): 1876 (Jan. several shocks).
Coningsby,	—	1818.
Copthall,	—	1750.
Convice (Scotland),	—	1845.
Conway,	—	1780.
Cork,	4	1755, 1766, 1820, 1868.
Cornwall,	3	1756, 1757, 1859.
Cove,	—	1820.
Coventry,	—	1666.
Coulomb (St.),	—	1757.
Crick,	-	1768.
Crickhowell,	—	1853.
Crieff,	6	1801, 1821, 1822, 1838, 1839, 1845.
Cremble Point,	—	1777.
Croughton,	—	1731.
Croydon,	—	1750.
Cumberland,	—	1843.
Dalkey (Dublin),	—	1852.
Dalmally,	—	1880.
Dalton,	2	1704, 1818.
Danichen (Scotland),	—	1808.
Danning (Perthshire),	—	1809.

Places.	No. of Occurrences in excess of one.	Years.
Darlington,	—	1768.
Dartford,	—	1727.
Dartmoor,	3	1752, 1858, ——.
Dawlish,	—	1865.
Deal,	4	1691, 1692, 1756, 1831.
Denbigh,	—	1780.
Derbyshire,	—	1683.
Derby,	3	1048, 1777, 1816.
Dingwell,	—	1880.
Doncaster,	4	1792, 1816, 1863, 1871.
Donegal (north part of),	—	1840.
Dorkin (Surrey),	—	1551.
Dorsetshire,	2	1750, 1853.
,, (coast of),	—	1839.
Dorchester,	—	1863.
Dover,	5	1580, 1692, 1756, 1776, 1831.
Dumbarton,	2	1755, 1820.
Downing,	3	1775, 1780, ——.
Dores (north of Scotland),	2	1817, ——.
Down (Scotland),	—	1821.
Drewsteignston (Dartmoor),	—	1858.
Druits (Ashburton),	—	1858.
Duddington,	—	1844.
Dudley,	—	1857.
Dumblane,	—	1842.
Dumfries,	2	1828, 1843.
Dublin,	5	1690, 1786, ——, 1852, 1863.
Dundry (Somersetshire),	—	1852.
Dunkeld (Scotland),	—	1822.
Dunston,	—	1822.
Durham County,	2	1179, 1866.
Easton,	—	1844.
Earraid,	—	1880.
Edenbridge,	—	1758.
Edinburgh,	2	1789, 1801.
Eltham,	—	1750.
Ely,	2	1105, 1165.

Places.	No. of Occurrences in excess of one.	Years.
Emsworth,	—	1824.
England (all),	29	974, 1043, 1076, ——, ——, ——, 1081, ——, 1085, 1089, 1090, 1099, 1117, 1119, 1153 (very violent), 1185, 1186, 1199, 1246, 1274, 1275, 1284, 1382, 1385, 1426, 1580, 1661, 1692, ——.
,, (north of),	2	1871, ——.
,, (centre of),	2	1863, 1864.
,, (west of),	—	1867.
,, (south-west of),	—	1868.
Enniscorthy (Ireland),	—	1863.
Epsom,	—	1750.
Everton (near Liverpool),	—	1863.
Exeter,	2	1748, 1868.
Exeter County,	—	1866.
Eyam Edge,	—	1755.
Fahan,	—	1880.
Fahring,	—	1734.
Falmouth,	5	1696, 1842, 1847, 1859, 1860.
Farnhurst,	—	1834.
Fleetwood,	—	1852.
Flint,	—	1780.
Flintshire,	—	1750.
Foord,	—	1880.
Fortwilliam (Scotland),	3	1869, 1870, 1880.
Frith of Clyde,	—	1871.
Frusham (north of Chudleigh),	—	1858.
Fulham,	—	1750.
Furness,	2	1865, 1871.
Gainsborough,	—	1777.
Garstang,	—	1871.
Glamorganshire,	2	1765, 1868.
Glasnevin (Dublin),	—	1852.
Glengarry (Scotland),	2	1833, 1839.
Glengeary (Dublin),	—	1852.
Gloucester,	2	1574, 1768.
Gloucestershire,	—	1812.
Glasgow,	6	1755, 1756, 1786, 1801, 1821, 1839.

Places.	No. of Occurrences in excess of one.	Years.
Glowson (Herefordshire),	—	1755.
Goodwood,	—	1734.
Goring,	—	1734.
Gosport,	3	1811, 1834, ——.
Grampion Hills,	2	1819, 1846.
Grassmore,	—	1871.
Great Malvern,	—	1868.
Greenock,	2	1755, 1821.
Grimstead, E.,	—	1758.
Gubbins,	—	1750.
Guernsey,	4	1750, 1761, 1843, ——.
Gwar Harold,	—	1853.
Hackney,	—	1750.
Hafodunos,	—	1780.
Halifax,	—	1738.
Hampshire Coast,	—	1834.
Hampshire,	—	1853.
Hanbury,	—	1678.
Handborough (Long),	—	1683.
Harborough,	—	1776.
Harrowgate,	—	1863.
Haslington,	—	1869.
Hatfield,	—	1750.
Havant,	2	1734, 1824.
Hayle (Land's End),	—	1860.
Headingley,	—	1871.
Headley (7 miles W. of Hazelmore)	—	1864.
Hebdenbridge,	—	1864.
Helston (Cornwall),	—	1842.
Hemborough (Gloucestershire)	—	1852.
Hempsted Court (Gloucestershire),	—	1865.
Hereford,	3	1574, 1853, 1868.
Herefordshire,	—	1755.
Hertfordshire,	—	1755.
Hertford,	—	1750.
Herne,	—	1843.
Holderness,	—	1818.
Holyhead,	3	1780, ——, 1852.

Places.	No. of Occurrences in excess of one.	Years.
Holywell,	—	1780.
Hopton (E. Harling),	—	1859.
Hope (Lancashire),	—	1869.
Horsham,	—	1833.
Hull,	—	1704.
Huntingdon,	—	1754.
Huddersfield,	—	1863.
Hynish,	—	1880.
Hyskeir,	—	1880.
Ilchester,	—	1726.
Innishowen Barony (Donegal),	—	1841.
Inverhallan,	—	1756.
Inverness,	8	1769, 1800, 1817, ——, ——, 1818, ——, 1880.
Invergeldy (6 miles N. of Comrie),	—	1843.
Inverary,	—	1880.
Iona,	—	1880.
Ireland (West of),	—	1756.
Irton,	—	1755.
Island Glass,	—	1880.
Island of Culla,	—	1880.
Jersey Island,	7	1750, 1790, 1804, 1843, ——, 1868, 1872.
Jethore,	—	1843.
Kanturk (Co. Cork),	—	1868.
Kelton (Stamford),	—	1844.
Kendal,	3	1768, 1865, 1871.
Kelvinside (Glasgow),	—	1880.
Kent,	3	1246, 1580, 1727.
Kent (coast of),	—	1776.
Kentchurch (Wales),	—	1853.
Keswick,	—	1787.
Kilkenny,	—	1690.
Killeen (Scotland),	—	1831.
Kilmartine,	—	1880.
Kilmichael,	—	1880.
Kilruddery (Dublin),	—	1852.

Places.	No. of Occurrences in excess of one.	Years.
Kingsbury (Parrett Valley),	—	1868.
Kingstown (Dublin),	—	1852.
Kingsdown,	2	1839, 1852.
Kinlockmordart (Argyleshire),	—	1841.
Kinsale,	—	1777.
Kintail (Ross-shire),	2	1820, 1841.
Kippin,	—	1820.
Kiston-in-Lindsay,	—	1818.
Kirkham,	—	1871.
Knole,	—	1867.
Knotsford,	—	1753.
Kyleakin,	—	1880.
Lambrook, E.,	—	1868.
Lamlash,	—	1880.
Lancashire,	6	1817, 1839, 1843, 1869 (east of), 1869, 1871.
Lancaster,	7	1750, 1777, 1786, 1835, 1842, 1868, 1868.
Langport (Parrett Valley),	—	1868.
Langridge,	—	1871.
Launceston,	—	1783.
Laxadale,	—	1880.
Leadhill,	3	1820, 1821, 1826.
Leamington,	—	1868.
Leeds,	3	1780, 1795, 1871.
Leicester,	3	1792, 1865, ——.
Leicestershire,	2	1750, 1776.
Lerwick (Shetland Islands),	—	1871.
Letterkenny,	—	1880.
Limavady,	—	1880.
Lincoln,	5	1142, 1185, 1704, 1792, 1816.
Lincolnshire,	2	1792, 1818.
Lingfield,	—	1758.
Lingstown,	—	1846.
Liphook,	2	1833, 1834.
Liskeard,	4	1837, 1852, 1858, 1860.
Lismore Lighthouse (Oban),	—	1841.
Llanvuhangel (Wales),	—	1853.
Llanwrest,	—	1780.
Llandovery,	—	1832.

Places.	No. of Occurrences in excess of one.	Years.
Longton,	—	1871.
Logierait Parish (Perthshire),	—	1763.
London,	13	1158, 1247, 1575, 1580, 1601, 1692, 1750, ——, ——, 1756, 1758, 1863, 1865.
Londonderry,	—	1880.
Liverpool,	5	1777, 1795, 1835, 1843, 1852.
Lostwithrel,	—	1757.
Longfleet (near Poole),	—	1834.
Lough Awe,	—	1818.
Loughborough,	—	1776.
Lough Durch,	—	1880.
,, Erne (Scotland),	2	1820, 1821.
,, Fyni,	—	1821.
,, Gair,	—	1880.
,, Ness,	—	1818.
Loughgilpead,	3	1843, ——, 1880.
Lowers (2 miles E. of Comrie),	—	1844.
Lowlandsman's Bay,	—	1880.
M'Arthur's Head,	—	1880.
Mallow (Co. Cork),	—	1868.
Malton,	—	1869.
Man (Isle of),	4	1786, ——, 1788, 1843.
Manchester,	9	1750, 1768, 1777, 1833, 1839, 1843, 1852, 1864, 1869, 1871.
Mansfield,	—	1817.
Maresfield (Sussex),	—	1864.
Margate,	—	1831.
Marizion,	—	1757.
Market-Rasen, E.,	—	1863.
Marlborough,	—	1868.
Martock,	—	1868.
Melton Lodge,	—	1868.
Mevagissey (Cornwall),	—	1860.
Michelney (Parret Valley),	—	1868.
Middle,	—	1688.
Middleton,	2	1820, 1869.
Mold,	—	1782.
Molesy, E.,	—	1750.

Places.	No. of Occurrences in excess of one.	Years.
Monach,	—	1880.
Monmouthshire,	2	1839, 1865.
Motherwell,	—	1880.
Mount's Bay,	—	1847.
Mull (Island of),	—	1877.
Neath,	—	1832.
Ness,	—	1880.
Netherlands (coasts of, and English),	—	1134.
Newcastle,	3	1780, 1768, 1871.
Newham (west of Penzance),	—	1850.
Newport,	4	1839, 1863, 1865, 1868.
Newquay (Land's End),	—	1860.
Norfolk (county),	3	1165, 1201, 1869.
Northair,	—	1750.
Northampton,	2	1750, 1776.
Northamptonshire,	2	1731, 1750.
Nottingham,	6	1110, 1792, 1816, 1865, 1868, 1873.
Nottinghamshire,	—	1750.
Norwich,	—	1795.
Oban (Argyleshire),	3	1841, ——, 1880.
Ochill Hills,	—	1734.
Oldham,	—	1869.
Omagh,	—	1880.
Ormskirk,	—	1871.
Oxenhall,	—	1179.
Oxford,	3	1666, 1683, 1764.
Oxfordshire,	—	1812.
Palborough,	—	1834.
Parret Valley,	—	1868.
Pendlebury,	—	1864.
Pendleton,	—	1869.
Penrith,	—	1787.
Pensford,	—	1852.
Penton,	—	1818.
Penzance,	6	1757, 1843, 1855, 1858, 1859, 1860.
Perth,	6	1597, 1801, 1816, 1824, 1846, 1852.
Perthshire,	—	1834.

Places.	No. of Occurrences in excess of one.	Years.
Pertree,	—	1880.
Peterborough,	2	1813, 1862.
Peterchurch (Wales),	—	1853.
Petworth,	—	1834.
Petherton,	—	
Phladda,	—	1880.
Pittochry (Scotland),	—	1842.
Plymouth,	6	1757, 1811, 1847, 1853, 1858, 1863.
Poole,	—	
Portaskaig,	—	1880.
Portree,	—	1880.
Portglasgow,	—	1820.
Portsmouth,	8	1691, 1734, 1750, 1811, 1824, 1834, —, 1853.*
Prescott,	—	1843.
Preston,	2	1843, 1871.
Ramelton,	—	1880.
Ramsgate,	2	1831, 1858.
Raphoe,	—	1880.
Rathmines (Dublin),	—	1863.
Reading,	—	1755.
Redruth,	4	1757, 1842, 1859, 1860.
Reigate,	—	1551.
Ripon,	2	1796, 1827.
Rochdale,	—	1864.
Rosegrave,	—	1869.
Rothsay,	—	1880.
Roydon,	—	1551.
Rugby,	—	1868.
Salford,	—	1864.
Salisbury,	—	1793.
Sandwich,	3	1691, 1776, 1848.
Sandwick,	—	1880.
Sark (Island of),	—	1843.
Scallasaig,	—	1880.
Scarborough,	2	1738, 1863.
Scilly Islands,	3	1757, 1771, 1847.

* Surface shaken estimated at 20,000 square miles.

Places.	No. of Occurrences in excess of one.	Years.
Scotland (south of),	—	1786.
,, (two-thirds of),	—	1839.
,, (north of),	—	1846.
,, (all of),	—	1872.
,, (west of),	—	1732.
Seavington,	—	1868.
Selby,	—	1704.
Shaftesbury,	3	1761, 1762, 1793.
Sheerness,	—	1692.
Sheffield,	—	1816.
Sheffield Park (Sussex),	—	1864.
Sherbourne,	2	1761, 1868.
Sherwood,	—	1868.
Shesdader,	—	1880.
Shrewsbury,	3	1110, 1838, 1839.
Shoreham,	—	1734.
Shropshire,	2	1712, 1836.
Silloth,	—	1871.
Silsden (York),	—	1864.
Skerryrore,	—	1880.
Skipton (York),	—	1864.
Somersetshire,	4	1199, 1680, 1752, 1868.
Southampton,	3	1750, 1834, 1853.
Sound of Mull,	—	1880.
Sowersby Bridge,	—	1869.
Smedly,	—	1869.
Staffordshire,	—	1678.
Stamford,	5	1755, 1792, 1813, 1837, 1844.
Stand,	—	1869.
Stanton,	—	1666.
Stepney,	—	1755.
Strathearn (Scotland),	2	1860, 1867.
Strathheam (near Crieff),	—	1821.
Strarvis (Devon),	—	1865.
Strathglass (Scotland),	—	*1853.*
Strabane,	—	1880.
Strome,	—	1880.
Stretton (Hereford),	—	1871.
Stronthian,	—	1732.

Places.	No. of Occurrences in excess of one.	Years.
Stirling, W.,	2	1767, 1801.
Stockport,	—	1750.
Stornoway,	—	1880.
Suffolk (shire),	4	1165, 1201, 1750, 1869.
Sunbury (Middlesex),	—	1865.
Sunderland,	—	1871.
Surrey,	—	1750.
Sussex,	2	1734, 1861.
Sutherland,	—	1690.
Sutton,	—	1727.
Swansea,	3	1775, 1832, ——.
St. Agnes,	—	1859.
St. Ives,	2	1757, 1860.
St. Just,	—	1860.
Stoke-sub-Hamilton,	—	1868.
Taunton,	2	1738, 1748.
Tavistock (mine),	—	1852.
Tenby (Pembrokeshire),	—	1864.
Threlkeld,	—	1787.
Tinover,	—	1844.
Tintinhull,	—	1868.
Tinwell,	—	1844.
Tobermory,	—	1880.
Todmorton,	—	1869.
Tohidy,	—	1757.
Tooting,	—	1750.
Truro,	—	1859.
Turnham,	—	1750.
Tyndrum,	2	1831, 1844.
Tynehead,	—	1838.
Tynemouth,	—	1865.
Tyne River,	—	1871.
Tinahely (Co. Wicklow),	2	1869, ——.
Ulg,	—	1880.
Ulverstone,	—	1863.
Urquart,	2	1817, ——.
Ushenich,	—	1880.
Usk,	—	1865.

Places.	No. of Occurrences in excess of one.	Years.
Waddridge,	—	1860.
Wales (the north of),	3	1780, 1827, 1842.
Wansford,	—	1844.
Warwick,	—	1750.
Waterloo (near Liverpool),	—	1868.
Waterloot,	—	1869.
Wattisfield (Suffolk),	—	1859.
Wattlington,	—	1688.
Wells,	2	1852, ——.
Wenlock,	3	1789, 1820, 1821.
Wenlock Head,	—	1828.
Westbury-on-Trym,	—	1852.
Westmoreland,	—	1817.
Weston-super-Mare,	2	1863, 1869.
Wexford,	2	1762, 1863.
Weymouth,	—	1853.
Wem (Shropshire),	—	1863.
Wicklow,	—	1760.
Widden (Land's End),	—	1860.
Wiltshire,	—	1764.
Winbourne,	—	1750.
Wight (Isle of),	2	1750, 1863.
Wheal Elden,	—	1859.
Whitchurch (Shropshire),	—	1863.
Whitehaven,	4	1755, 1780, 1786, ——.
Woodhouse,	—	1871.
Woodhouse Eaves (Charnwood Forest),	—	1838.
Wolverhampton,	2	1677, 1678.
Worcester,	5	1048, 1574, 1768, 1868, ——.
Worcestershire,	—	1868.
Wordsley (Worcestershire),	—	1863.
Worth (Parish of),	—	1758.
Wrexham,	—	1750.
Wye (river basin),	—	1853.
York,	5	1201, 1574, 1754, 1780, 1821.
Yorkshire,	3	1738, 1817 (west of), 1869.

EARTHQUAKE MAP
OF THE
BRITISH ISLANDS

REDUCED ONE HALF FROM ORIGINAL DRAWING.

FÆRÖE Is

SHETLAND Is

ORKNEY Is

PENTLAND FIRTH

NORTH MINCH

WESTERN ISLES OR HEBRIDES

LITTLE MINCH

SKYE

SEA OF THE HEBRIDES

FIRTH OF MORAY

Inverness

CALEDONIAN CANAL

SCOTLAND

ROCKALL BANK

VIDAL BANK

NORTH ATLANTIC OCEAN

NORTH SEA

FIRTH of FORTH

Stirling

Dumbarton

Glasgow

EDINBURGH

NORTH CHANNEL

FIRTH of CLYDE

Dunfries

Carlisle

E. Tyne

Durham

FIRTH of SOLWAY

Whitehaven

Kendal

Scarborough

ISLE OF MAN

MORECAMBE B.

Lancaster

York

Hull

LIVERPOOL B.

Manchester

Liverpool

Sheffield

Lincoln

HOLYHEAD

ANGLESEA

CAERNARVON B.

Nottingham

Derby

Peterborough

Birmingham

CARDIGAN BAY

IRISH CHANNEL

WALES

ENGLAND

Northampton

Cambridge

Bedford

Buckingham

Brecknock

Gloucester

Oxford

Chelmsford

Rochester

LONDON

Cardiff

Bristol

Canterbury

BRISTOL CHANNEL

Salisbury

Portsmouth

Chichester

Brighton

DOVER STR.

Calais

Boulogne

Exeter

Dorchester

Launceston

Abbeville

Dieppe

ENGLISH CHANNEL

Cherbourg

Havre

Rouen

St Malo

FRANCE

IRELAND

Londonderry

Donegal

Omagh

Antrim

Belfast

Armagh

DONEGAL BAY

Galway

GALWAY B.

DUBLIN

Kilkenny

Wexford

Mallow

Cork

Queenstown

DINGLE B.

R. St Lawrence G.C.

Canceaux Mts G.C.

W. Coast of Portugal G.C.

Mts of Mercy G.C. Area

Suppposed axis of Coal and Lenda Basin

Salisbury

Portsmouth

Chichester

Brighton

Exeter

Dorchester

Launceston

Abbeville

Dieppe

Cherbourg

Havre

Rouen

St Malo

FRANCE

2 MENTIONS 3 4 5 6 7 8 9 10 14

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XVIII.—*Report on some recent Foraminifera found off the Coast of Dublin and in the Irish Sea.* By Frederick Pryor Balkwill, and Joseph Wright, F. G. S. (Plates XII., XIII., and XIV.)

[Read, 23rd June, 1884.]

When undertaking the present work it was our intention to have taken dredgings off the coasts of Dublin and Wicklow, an intention that was frustrated by unforeseen difficulties, which prevented our programme being carried out in its original shape. This Report, therefore, relates to Dublin, with the addition of some important gatherings taken in the Irish Sea, these being the limits to which it seemed desirable to confine our researches. Previous to the commencement of this undertaking, one of us had made a number of shore gatherings in the vicinity of Dublin, and a list of the Foraminifera then found was communicated to the Academy.* For the sake of completeness these species also appear in the present enumeration.

Having engaged a fishing smack of forty tons, and the weather being favourable, we put out on the 9th of May, 1881, for the purpose of commencing our dredgings off the Dublin coast. Three consecutive days were occupied in this manner, the only drawback being the lightness of the winds, which failed us at times. We were in consequence unable to reach a sufficient distance from land, and had to confine our operations to the shallow water, comparatively near the shore. We were fortunate to have for our skipper one whose practical knowledge of the ground, and skill in working the dredges, largely contributed to the number of gatherings we were able to secure, the dredges rarely coming up empty. Thirty gatherings were taken—three in Dublin Bay, the remaining twenty-seven off the coast extending from Ireland's Eye to Bray Head, and as far off land as the Kish and Bray Banks, the greatest depths dredged being off Bray Head, 27 fathoms.

* *Proceedings* R. I. Acad., vol. iii., 2nd Ser., Science, p. 545.

Two months later other dredgings were taken, in which we were joined by Prof. Haddon, who kindly placed a yacht at our disposal. The following day we were under a similar obligation to Thomas Arthur Bewley, Esq., for the use of a steam launch: on both these occasions the weather proved unfavourable, only six gatherings being secured, and these not far from land.

Early the following year (February, 1882,) we gave the Academy (*loc. cit.*) a short preliminary sketch of what we had accomplished, with a list of the Foraminifera found; it included also a report on certain material collected by Mr. Voysey in the Irish Sea, which he had submitted to us for examination. One hundred and thirty-nine species and varieties of Foraminifera were recorded in this communication, two being new to Britain, and two new to science. Considering the short space of time spent in examining this part of our coast, these results were most encouraging, and left little doubt but that a renewed search, especially in deeper water than we had hitherto explored, would still further increase the numbers, and lead to the discovery of other rare forms.

In August, 1882, we renewed the work of exploration, and engaged a fishing smack, much larger than the vessel previously used. We were again fortunate in engaging the services of an excellent skipper, Mr. Voysey, the gentleman who had on various occasions supplied us with material from the Irish Sea, and whose thorough knowledge of the nature of the sea-bottom in these parts now proved to be of the greatest service to us. The weather was, as on the previous occasion, exceptionally fine; but again we were greatly retarded from want of wind, and for the greater part of one day we were all but becalmed. The special object we had in view at this time was to secure gatherings from deep water, the parts near the coast having already been well examined. The whole of the first day and night was spent in going from Dublin to the part dredged by us, marked on the chart as "Lambay Deep," and situated about thirteen miles N. E. of the entrance to Dublin Bay. It was most desirable that this place should be visited, as here occurs the deepest water within many miles of Dublin, the sounding line showing at one place 73 fathoms. At daybreak on the morning of the second day (Tuesday, 8th,) we sounded in 45 fathoms, and soon afterwards

had the satisfaction of seeing two small dredges landed on the deck, filled with an oozy mud. The greater part of the day was spent dredging about this place. Towards evening, seven miles further east, we took two hauls in 50 fathoms, an oozy mud being again brought up, similar to what was collected in the morning. On the following morning (Wednesday, 9th,) about seven miles S. W. of last locality, in a dense fog, a haul was taken in 48 fathoms, the material being somewhat similar to that found on the previous day, but more sandy; and again, two miles to the S. W., another haul was taken in 40 fathoms, fine sand being brought up. By this time the wind had almost entirely died away; but the special object we had in view—to take dredgings in the deep water off Dublin—had been attained, so we now pressed on all canvas and hastened homewards, only taking two gatherings on the way back.

The dredgings taken at Lambay Deep in 45 fathoms, and those taken seven miles further east in 50 fathoms, require more than a passing comment. The material gathered in 45 fathoms yielded 118 species, whilst that in 50 fathoms only 108 species. The difference in these numbers may be easily accounted for by the much greater quantity of material obtained at the first mentioned place; but in every other respect they were similar, and may be regarded as one locality: no other spot off the British coast has yielded so large a number of species, or so many rare and interesting forms. *Lagena castrensis*, Schwager; *Rhabdogonium tricarinatum*, d'Orbigny; and *Pullenia quinqueloba*, Reuss, are only known as British species from this locality. Among the many other rare species found here, the following may be mentioned:—*Miliolina tenuis*, *Cornuspira foliacea*, *Psammosphæra fusca*, *Haplophragmium agglutinans*, *Ammodiscus charoides*, *Textularia globulosa*, *Bulimina subteres*, *Lagena curvilineata*, *Lingulina carinata*, *Nodosaria raphanus*, *N. radicula*, and *Marginulina glabra*, abundant; *Uvigerina pygmæa*, and *Gypsina lævis*. *Biloculinæ*, *Buliminæ*, and *Lagenæ*, were in great abundance; as also the following arenaceous forms, *Hyperammina elongata*, *Reophax scorpiurus*, and *Haplophragmium pseudospirale*. It was most instructive to observe how these arenaceous Foraminifera became gradually rarer, and eventually disappeared, as we changed from mud to sand in places not far

separated and differing only slightly in depth, as the following table will show:—

	Stations 34 and 35. Lambay Deep. 45 to 50 fathoms. Mud.	Station 36. Near Lambay Deep. 48 fathoms. Mud and Sand.	Station 37. Near Lambay Deep. 40 fathoms. Sand.
Hyperammina elongata, .	Very common.	Rare.	None.
Reophax scorpiurus, . .	Very common.	Rare.	None.
Haplophragmium pseudospirale,	Very common.	None.	None.

In addition to that collected by ourselves, we received from Mr. Voysey the material of a number of gatherings which had been obtained by him whilst trawling in the Irish Sea. The Foraminifera found by us in these gatherings are given in the distribution table columns as A to F. Two of these gatherings were of mud which had been taken from the mouths of fishes (*Lophius piscatorius*, Linn.); one was taken in deep water, off the Mourne Mountains, the other fourteen miles off Howth. Both were exceptionally rich in Foraminifera, the only good examples we have seen of *Bulimina aculeata* were got from this material.

Several of the names given in our preliminary Report, published two years ago, do not appear in the present Memoir. One or two of these were of somewhat doubtful forms, which it is thought better to omit. The others were Foraminifera, which we now consider should be merged into species already recorded; these we have noticed under their respective species. The Foraminifera in the list now appended, number one hundred and forty-seven species and varieties, ten of these being new to Britain and three new to Science.

Some years ago one of us examined the coast of Down and Antrim* for Foraminifera, the deepest parts dredged being in the vicinity of the Maiden Light Houses 60–70 fathoms. It may be of interest to compare the

* J. Wright, Rec. For. of Down and Antrim, *Proc. Belfast Nat. Field Club*, 1876–7.—App.

Foraminifera found in those dredgings, taken in the Northern Channel, with those found off Dublin and in the Irish Sea adjoining. As might have been expected, there was but little difference in the Rhizopodal fauna of these places. Certainly a much greater number of forms were obtained off Dublin, but many of these were very rare, frequently only one or two specimens being found. *Marginulina glabra*, found in several of the Dublin dredgings and common at Lambay Deep, 45–50 fathoms, did not occur in the Northern Channel. *Textularia agglutinans* (not typical), *Pulvinulina repanda*, and *Truncatulina refulgens* were common in deep water in the Northern Channel: the first mentioned came up very rarely off Dublin, and the others were entirely absent. Little value should be attached to *Reophax scorpiurus* and *Hyperammina elongata* occurring in such abundance at Lambay Deep, although the former is very rare, and the latter absent in the Northern Channel, as these two species were only found off Dublin where the bottom was muddy, and the dredgings in the Northern Channel yielded sand exclusively.

In conclusion, we have to thank those gentlemen who kindly gave us assistance in the preparation of this Paper. To H. B. Brady, F.R.S., we are deeply indebted for the kind and liberal help we have at all times received from him in the identification of critical species, and his advice and suggestions during the progress of the work have been of the utmost value. Mr. Brady has also placed us under further obligations by allowing us to consult the proof sheets of the scheme of classification in the Synopsis of Genera adopted in his Report on the Challenger Foraminifera, which he generously placed at our disposal to work from.*

We are much indebted to S. M. Malcomson, M.D., for the very accurate drawings which accompany this Report. Our thanks are also due in an especial manner to A. T. Hollick, Esq., for the care and skill bestowed in transferring them to stone. Mr. Hollick has, however, had the original specimens before him in all cases.

We have to thank Thomas Alcock, M.D., of Manchester, and Charles Elcock, Esq., of Belfast, for the loan of specimens of two rare Foraminifera which we have figured in the accompanying plates.

* Proof "Voyage H. M. S. Challenger."—*Zoology*, v. ix., *Report on Foraminifera*, pp. 60–76.

And lastly, we must not omit to mention our obligations to Stephen Voysey, Esq., who collected for us a number of gatherings in the Irish Sea, which have materially increased the value of this Paper.

The following is a detailed synopsis of the Foraminifera found :—

SUB-KINGDOM.—PROTOZOA.

CLASS.—RHIZOPODA.

ORDER.—Foraminifera—(Reticularia).

Family.—MILIOLIDÆ.

Sub-family.—MILIOLININÆ.

Biloculina, d'Orbigny.

Biloculina ringens, Lamarck, sp. (Pl. XII. figs. 6, 7).

Miliolites ringens, Lamarck, 1804, Ann. du Muséum, vol. v. p. 351, vol. ix., pl. 17, fig. 1; *Biloculina elongata*, d'Orbigny, 1826, Ann. Sci. Nat., vol. vii., p. 298, No. 4.

Professor Williamson's figures (Rec. For. Gr. Br., pl. 6, figs. 169, 170, and pl. 7, fig. 171) give a very accurate representation of this species, as it is usually found around the British coast. *B. elongata*, d'Orbigny, we regard as an elongated form of this species, and we believe that the two pass into one another. Frequent.

A small thin-shelled sphærical variety, with a crescentic slit-aperture (Pl. XII. figs. 6, 7) was found in abundance at Lambay, depth 45–50 fathoms; it occurred sparingly at a few other stations in the Irish Sea.

Biloculina depressa, d'Orbigny.

Biloculina depressa, d'Orbigny, 1826, Ann. Sci. Nat., vol. vii., p. 298, No. 1.

Found nearly everywhere, abundant in deep water.

Spiroloculina, d'Orbigny.

Spiroculina limbata, d'Orbigny.

Spiroloculina limbata, d'Orbigny, 1826, Ann. Sci. Nat., vol. vii., p. 299, No. 12.

Rare, specimens small.

Spiroloculina planulata, Lamarck, sp.

Miliolites planulata, Lamarck, 1805, Ann. du Muséum, vol. v., p. 352, No. 4.

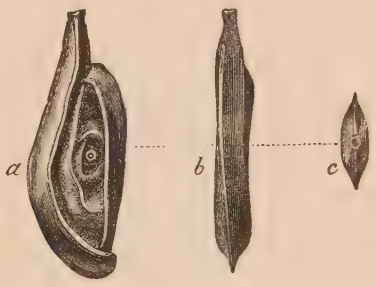
Rare, specimens small.

Spiroloculina acutimargo, Brady (woodcut).

Spiroloculina acutimargo, Brady, 1884, Rep. Voy. H.M.S. Challenger, vol. ix., p. 154, pl. 10, figs. 12–15.

Very rare. The trivial name accurately describes the sharp edge of this shell, which is well shown in the woodcut annexed. (Fig. 1.) The few specimens found off the Dublin coast were poor, and much smaller than those which occur in tropical seas.

FIG. 1.



Spiroloculina acutimargo. × 80.
a. lateral aspect. *b*. edge view. *c*. oral aspect.
Lambay, depth 45 fathoms.

Miliolina, Williamson.

Miliolina trigonula, Lamarck, sp.

Miliolites trigonula, Lamarck, 1804, Ann. du Muséum, vol. v., p. 351, No. 3.

Generally distributed, but rather rare at most localities.

Miliolina tricarinata, d'Orbigny, sp.

Triloculina tricarinata, d'Orbigny, 1826, Ann. Sci. Nat., vol. vii., p. 299, No. 7; Modèles No. 94.

Rare.

Miliolina oblonga, Montagu, sp.

Vermiculum oblongum, Montagu, 1803, Test. Brit., p. 522, pl. 14, fig. 9.

Rather rare.

Miliolina seminulum, Linn., sp.

Serpula seminulum, Linn., 1767, Syst. Nat. 12th ed., p. 1264, No. 791.

Abundant everywhere.

Miliolina tenuis, Czjzek, sp. (Pl. XII. figs. 3–5).

Quinqueloculina tenuis, Czjzek, 1847, Haidinger's Naturwiss. Abhandl. vol. ii., p. 149, pl. 13, figs, 31–34.

This simple little shell is somewhat spiroloculine in aspect and twisted on itself. Only found in a few deep-water gatherings in the Irish Sea; at Lambay, depth 45–50 fathoms, it was rather plentiful, the specimens being fairly large and typical.

Miliolina subrotunda, Montagu, sp. (Pl. XII. figs. 8, 9).

Vermiculum subrotundum, Montagu, 1803, Test. Brit., part. 2, p. 521.

Most abundant everywhere.

Miliolina secans, d'Orbigny, sp.

Quinqueloculina secans, d'Orbigny, 1826, Ann. Sci. Nat., vol. vii., p. 303, No. 43; Modèles No. 96.

Generally distributed, very fine, and abundant in some of the shore gatherings, but rare in deep water.

Miliolina bicornis, Walker and Jacob, sp.

Serpula bicornis, Walker and Jacob, 1798, (fide Kanmacher), Adams' Essays, 2nd ed. p. 633, pl. 14, fig. 2.

Frequent, nearly everywhere.

Miliolina ferussacii, d'Orbigny, sp.

Quinqueloculina ferussacii, d'Orbigny, 1826, Ann. Sci. Nat., vol. vii., p. 303, No. 42.

Frequent, nearly everywhere.

Miliolina ferussacii, d'Orbigny, sp. *var.* (Pl. XII. figs. 10–12).

A coarse roughened variety of this species, at times somewhat sandy, approaching *M. sclerotica*, Karrer. The peripheral margin is flat and very broad at its base. Not unfrequent in shallow water and shore gatherings.

Miliolina pulchella, d'Orbigny, sp.

Quinqueloculina pulchella, d'Orbigny, 1826, Ann. Sci. Nat., vol. vii., p. 303, No. 42.

Only a few poor specimens were found in the Dublin gatherings. The finest British examples we have seen of this very beautiful but rare species were got in dredgings taken in Marlpool, Strangford Lough, depth 20–25 fathoms,* where they occurred plentifully; they had strong, bold, longitudinal costæ, the surface being ornamented with longitudinal striæ. These specimens closely resemble that figured by Soldani. (*Testae*, vol. ii. p. 53, pl. 18, fig. *f.*)

Miliolina agglutinans, d'Orbigny, sp. (Pl. XIII. figs. 1–3).

Quinqueloculina agglutinans, d'Orbigny, 1839, Foram. Cuba, p. 168, pl. 12, figs 11–13.

A coarse-grained arenaceous Miliolina, in shape like a plum-stone, septal lines very indefinite. This shell has probably been often overlooked from its rude appearance and general resemblance to a pellet of hardened sand. Very rare, found at only one or two stations.

Miliolina fusca, Brady, sp.

Quinqueloculina fusca, Brady, 1870, Ann. and Mag. Nat. Hist., Ser. 4, vol. vii., p 47, pl. 11, fig. 2.

The occurrence of this arenaceous Miliolina may nearly always be looked on as indicative of brackish water. Very rare.

* J. Wright "Rec. For. Down and Antrim," *Proc. Belfast Nat. Field Club*, 1876–7.

Sub-family.—HAUERININÆ.

Ophthalmidium, Kübler.

Opthalmidium carinatum, nov. sp. (Pl. XII. figs. 13–16).

Shell much compressed, subdiscoidal, equilateral, showing all the convolutions; peripheral margin with a narrow keel, composed of a few convolutions slightly embracing; segments few, swollen at the base and getting narrower towards the superior end, each forming about two-thirds of a convolution; aperture simple, terminal.

We have placed this shell under Ophthalmidium, as being the genus to which it appears most nearly allied; it, however, differs from it somewhat in the convolutions being septate from their commencement, the forms hitherto recorded having their earlier convolutions non-septate. From Hauerina it differs in having an open aperture (not cribriform), and from Spiroloculina in the chambers forming two-thirds of a convolution, and not alternating at opposite extremities, as in that genus.

This interesting little rhizopod has probably hitherto been overlooked from its small size and general resemblance to Miliolina subrotunda, Mont., to which, however, it has no real relationship. We are indebted to Mr. Charles Elcock for first drawing our attention to this species, which is generally distributed around the Irish coast.

Sub-family.—PENEROPLIDINÆ.

Cornuspira, Schultze.

Cornuspira foliacea, Philippi, sp. (Pl. XII. figs. 1 *a*, 1 *b*).

Orbis foliaceus, Philippi, 1844, Enum, Moll. Sicil. vol. ii., p. 147, pl. 24, fig. 26.

A large and beautiful shell, very fragile, specimens nearly always in a more or less broken condition. A few perfect examples were dredged at Lambay, depth, 45–50 fathoms. Rare.

Cornuspira involvens, Reuss, sp. (Pl. XII. figs. 2 *a*, 2 *b*).

Operculina involvens, Reuss, 1849, Denkschr. Akad. Wien., vol. i., p. 370, pl. 45, fig. 20.

Found in nearly all the Dublin gatherings, but not frequent in any of them.

Family.—ASTRORHIZIDÆ.

Sub-family.—Pilulininæ.

Technitella, Norman.

Technitella legumen, Norman.

Technitella legumen, Norman, 1878, Ann. and Mag. Nat. Hist., ser. 5, vol. i., pl. 16, figs. 3, 4.

A very interesting form, having the test entirely built up of delicate sponge spicules, arranged longitudinally side by side with the most marvellous precision. Only a few specimens were found by us in the Irish Sea. Mr. Charles Elcock has since met with this species in considerable abundance in mud, dredged in the Irish Sea, midway between the Mourne Mountains and the Isle of Man, 70 fathoms.

Sub-family.—Saccamminiæ.

Psammosphæra, Schulze.

Psammosphæra fusca, Schulze.

Psammosphæra fusca, Schulze, 1874, II. Jahresbericht d. Comm. Untersuch. d. deutschen Meere in Kiel, p. 113, pl. 2, fig. 8, a-f.

Some small, neat, sphærical arenaceous forms of a grey colour were occasionally met with in the deep water gatherings. We regard these as weak specimens of *P. fusca*.

Sub-family.—RHABDAMMININÆ.

Hyperammina, Brady.

Hyperammina elongata, Brady (Pl. XIII. figs. 4 *a*, 4 *b*).

Hyperammina elongata, Brady, 1878, Ann. and Mag. Nat. Hist., ser. 5, vol. i., pl. 20, fig. 2.

Large and very abundant at Lambay, depth 45–50 fathoms, muddy bottom; it was also met with, but not so plentifully, at a few other places in the Irish Sea.

Family.—LITUOLIDÆ.

Sub-family.—LITUOLINÆ.

Reophax, Montfort.

Reophax fusiformis, Williamson, sp.

Proteonina fusiformis, Williamson, 1858, Rec. For. Gr. Br., p. 1, pl. 1, fig. 1.

Rather rare.

Reophax scorpiurus, Montfort (Pl. XIII. figs. 5 *a*, 5 *b*).

Reophax scorpiurus, Montfort, 1808, Conchyl. Syst. vol. i., p. 330, 83e genre.

Many of the specimens have the septal partitions rudimentary, showing a tendency to run into *R. fusiformis*, Will. Abundant at Lambay, depth 45–50 fathoms; also found at one or two other stations in the Irish Sea, but not so plentifully.

Reophax (?) sp. (Pl. XIII. figs. 9, 22–24).

Fragments of a straight, slender, arenaceous form, consisting of a number of segments of uniform thickness, have been found by us occurring at many places around the Irish coast. The test is composed of sand grains or of closely-fitting sponge spicules, arranged longitudinally, side by side, and cemented together by a hard, ferruginous material. The spicules

are never free, but are always imbedded in the test. When the shell is formed of sand grains it closely resembles the uniserial portion of *Bigenerina digitata*, d'Orbigny, and we think it not improbable that the specimens which were recorded by this name in Brady's Catalogue of Recent Foraminifera, Northumberland and Durham,* were similar to ours. Mr. Siddall, in the Foraminifera of the River Dee,† refers similar fragments to *Lituola findens*, Parker, but we cannot agree in this determination. We have not yet met with any perfect examples of this form, although we must have collected at least 200 specimens, and, consequently, are unable to say with any degree of certainty to what genus it should be referred. It is not, however, improbable but that these fragments may be portions of some parasitic rhizopod. Were such the case, it would account for the broken condition in which it has been hitherto found.

Haplophragmium, Reuss.

Haplophragmium glomeratum, Brady, sp.

Lituola glomerata, Brady, 1878, Ann. and Mag. Nat. Hist., ser. 5, vol. i., p. 433, pl. 20, fig. 1, a, b, c.

Rather rare, and the specimens small. This species has been found plentifully in Killybegs Harbour, depth 7–17 fathoms, muddy bottom; it has also been met with by Mr. Robertson in Portree Bay, Skye, depth 14–18 fathoms.

Haplophragmium globigeriniforme, Parker and Jones, sp.

Lituola globigeriniformis, Parker and Jones, 1865, Phil. Trans. vol. clv., p. 407, pl. 15, figs. 46, 47, and pl. 17, figs. 96–98.

Generally distributed, rare in shallow water and shore gatherings, frequent in deep water.

* Nat. Hist. Trans. Northumberland and Durham, vol. i., part 1, p. 102.

† Proc. Chester Soc. Nat. Sci., 1878, part 2, p. 47.

Haplophragmium pseudospirale, Williamson, sp. (Pl. XIII. figs. 6–8).

Proteonina pseudospiralis, Williamson, 1858, Rec. For. Gr. Br. p. 2, pl. 1, figs. 2, 3.

Very fine examples of this species were met with in profusion at Lambay, depth 45–50 fathoms; it was also common at two localities in the Irish Sea, but except at these places was rarely met with off the Dublin coast.

Haplophragmium agglutinans, d'Orbigny, sp. (Pl. XIII. figs. 18–20).

Spirolina agglutinans, d'Orbigny, 1846, For. Foss. Vien., p. 137, pl. 7, figs. 10–12.

Test crozier-shaped, coarsely arenaceous, linear portion very elongate cylindrical, septal lines obscure. Very rare, found only at two stations. This species has also been obtained by Mr. Millett off the Isle of Wight.

Haplophragmium canariense, d'Orbigny, sp.

Nonionina canariensis, d'Orbigny, 1839, Foram. Canaries, p. 128, pl. 2, figs, 33, 34.

Frequent everywhere.

Sub-family.—TROCHAMMININÆ.

Ammodiscus, Reuss.

Ammodiscus incerta, d'Orbigny, sp.

Operculina incerta, d'Orbigny, 1839, Foram. Cuba, p. 49, pl. 6, figs. 16, 17.

Very rare.

Ammodiscus gordialis, Jones and Parker, sp.

Trochammina gordialis, Jones and Parker, 1860, Quart. Jour. Geol. Soc., vol. xvi. p. 304, No. 88; Wright, 1877, Proc. Belfast Nat. Field Club, App. pl. 4, fig. 3.

Very rare.

Ammodiscus charoides, Jones and Parker, sp. (Pl. XIII. fig. 10).

Trochammina charoides, Jones and Parker, 1860, Quart. Jour. Geol. Soc., vol. xvi. p. 304.

Only three or four small poor examples were found.

Ammodiscus shoneana, Siddall, sp.

Trochammina shoneana, Siddall, 1878, Proc. Chester Soc. Nat. Sci. part 2, p. 46.

Only three examples were met with in the Dublin gatherings. Quite a number of specimens were found by Dr. Malcomson in shore gatherings at Rockport, Belfast Lough.

Trochammina, Jones and Parker.

Trochammina squamata, Jones and Parker.

Trochammina squamata, Jones and Parker, 1860, Quart. Jour. Geol. Soc. vol. xvi. p. 304, No. 88 ; 1864, Phil. Trans., vol. clv. p. 407, pl. 15, figs. 30, 31.

Frequent at most localities. A very beautiful variety with flush chambers (*R. ochracea*, Williamson, Recent Foraminifera, Gr. Br. pl. 4, fig 112, and pl. 5, fig. 113,) was found rather sparingly in some of the gatherings; it was much rarer than the typical form.

Trochammina inflata, Montagu, sp.

Nautilus inflatus, Montagu, 1808, Test. Brit. Suppl., p. 81, pl. 18, fig. 3.

Very rare, its occurrence is almost entirely restricted to brackish water.

Trochammina inflata, Montagu, sp. *var.* (Pl. XIII. figs. 11, 12).

A somewhat conical, many-chambered variety of this species was found in deep water off Dublin, and in the Irish Sea. Rare.

Trochammina macrescens, Brady.

Trochammina macrescens, Brady, 1870, Ann. and Mag. Nat. Hist., ser. 4, vol. vi. p. 290, pl. 11, fig. 5, a–c.

Very rare.

Family.—TEXTULARIDÆ.

Sub-family.—TEXTULARINÆ.

Textularia, Defrance.

Textularia sagittula, Defrance (Pl. XIII. figs. 15–17).

Textularia sagittula, Defrance, 1824, Dict. Sci. Nat., vol. xxxii. p. 177; vol. li p. 344; De Blainville, Malacologie, p. 370, pl. 5, fig. 5.

This species is closely allied to *T. gramen*, d'Orbigny, but differs from it in being more elongated, having the sides nearly parallel, and the peripheral margin more sharply angular. Rare.

Textularia gramen, d'Orbigny (Pl. XIII. figs. 13, 14).

Textularia gramen, d'Orbigny, 1846, For. Foss. Vien. p. 248, pl. 15, figs. 46.

Frequent at most places.

Textularia agglutinans, d'Orbigny.

Textularia agglutinans, d'Orbigny, 1840, Foram. Cuba, p. 136, pl. 1, figs. 17, 18, 32-34.

We obtained very few examples of this species, and the specimens found were small and obscure.

Textularia globulosa, Ehrenberg.

Textularia globulosa, Ehrenberg, 1839, Abhandl. Akad. Berlin, 1838, p. 135, No. 60, pl. 4, several figures.

This pretty little Textularia is very rare off Dublin. It occurs very abundant fossil in the chalk of the North of Ireland.

Verneuilina, d'Orbigny.

Verneuilina polystropha, Reuss.

Verneuilina polystropha, Reuss, 1846, Boëhm. Kreid., vol. ii. p. 109, pl. 24, fig. 53.

Frequent.

Verneuilina spinulosa, Reuss.

Verneuilina spinulosa, Reuss, 1849, Denkschr. Mathem. Natur. Cl. K. Akad. Wissench. Wien, vol. i., p. 374, pl. 47, fig. 12.

Only two poor examples were found.

Dimorphous (*Textularian*) *forms.*

Spiroplecta, Ehrenberg.

Spiroplecta biformis, Parker and Jones (Pl. XIII. fig. 21).

Textularia agglutinans, var. *biformis*, Parker and Jones, 1864, Phil. Trans., vol. clv. p. 370, pl. 15, figs. 23, 24.

Only one or two examples were found. This form has hitherto been only known as British, from specimens found by Dr. Malcomson in shore gatherings at Rockport, Belfast Lough. A woodcut (Fig. 2) of one of these specimens is annexed, as they are much finer than those found off the Dublin coast.

FIG. 2.

Spiroplecta biformis × 80. Rockport, Belfast Lough.

Gaudryina, d'Orbigny.

Gaudryina filiformis, Berthelin.

Gaudryina filiformis, Berthelin, 1880, Mem. Soc. Geol. France, Ser. 3, vol. i. Mem. No. 5, p. 25, pl. 1, figs. a–d.

Rather rare.

Sub-family.—BULIMININÆ.

Bulimina, d'Orbigny.

Bulimina pupoides, d'Orbigny.

Bulimina pupoides, d'Orbigny, 1846, For. Foss. Vien. p. 185, pl. 11. figs. 11, 12.

Common everywhere.

Bulimina marginata, d'Orbigny.

Bulimina marginata, d'Orbigny, 1826, Ann. Sci. Nat., vol. vii., p. 269, pl. 12, figs. 10–12.

Generally distributed, but rather rare at most places.

Bulimina aculeata, d'Orbigny.

Bulimina aculeata, d'Orbigny (after Soldani), 1826, Ann. Sci. Nat., vol. vii. p. 269, No. 7; *Bulimina pupoides*, var. *spinulosa*, Williamson, 1858, Rec. For. Gr. Br., p. 62, pl. 5, fig. 28.

This beautiful form was found abundant in mud, which was got in the mouths of two fishes (*Lophius piscatorius*, Linn.) taken in deep water off the Louth coast, the delicate spines which ornament the shell being in fine preservation. Only a few specimens were met with in the other gatherings.

Bulimina ovata, d'Orbigny.

Bulimina ovata, d'Orbigny, 1846, For. Foss. Vien. p. 185, pl. 11, figs 13, 14.

Frequent.

Bulimina elegantissima, d'Orbigny.

Bulimina elegantissima, d'Orbigny, 1839, Voyage l'Amér. Mérid. p. 51, pl. 12, figs. 13, 14.

Generally distributed, rather rare at most places.

Bulimina subteres, Brady.

Bulimina subteres, Brady, 1880, Quart. Jour. Micr. Sci., vol. xxi. New Series, p. 25; Wright, 1881, Proc. Belfast Nat. Field Club, App. pl. 8, fig. 2.

Only one or two specimens were found. A good many well-grown examples of this rare and elegant Bulimina were obtained in dredgings taken in Killybegs Harbour, depth 7–17 fathoms.

Virgulina, d'Orbigny.

Virgulina schreibersiana, Czjzek.

Virgulina schreibersiana, Czjzek, 1847, Haidinger's Naturwiss. Abhandl., vol. ii. p. 147, pl. 13, figs. 18–21.

Rare.

Bolivina, d'Orbigny.

Bolivina textilarioides, Reuss.

Bolivina textilarioides, Reuss, 1862, Sitzungsb, d. k. Ak. Wiss. Wien., vol. i. p. 38, pl. 48, fig. 15.

Rare.

Bolivina punctata, d'Orbigny.

Bolivina punctata, d'Orbigny, 1839, Voyage l'Amér. Mérid. p. 63, pl. 8, figs. 10–12.

This form has frequently delicate longitudinal striæ on the earlier chambers. Frequent.

Bolivina plicata, d'Orbigny.

Bolivina plicata, d'Orbigny, 1839, Voyage l'Amér. Mérid., p. 62, pl. 8, figs. 4–7.

Frequent.

Bolivina dilatata, Reuss.

Bolivina dilatata, Reuss, 1849, Denkschr. d. k. Ak. Wiss. Wien., vol. i. p. 381, pl. 48, fig 15.

Very rare.

Bolivina difformis, Williamson, sp.

Textularia difformis, Williamson, 1858, Rec. For. Gr. Br., p. 77, pl. 6, figs. 166, 167.

We have placed this species with the Bolivinæ, as it has the infolded notch-like aperture characteristic of the genus. Very rare.

Sub-family.—Cassidulininæ.

Cassidulina, d'Orbigny.

Cassidulina lævigata, d'Orbigny.

Cassidulina lævigata, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 271, No. 5, Modèles, No. 38.

Very rare.

Cassidulina crassa, d'Orbigny.

Cassidulina crassa, d'Orbigny, 1839, Voyage l'Amér. Mérid., vol. v. p. 56, pl. 7, figs. 18–20.

Rather rare off Dublin, specimens small and poor. This species has been obtained at many places around the Irish coast. *C. oblonga*, d'Orbigny, is an oblong form of this species; it was found in several of the Dublin gatherings.

Family.—LAGENIDÆ.

Sub-family.—LAGENINÆ.

Lagena, Walker and Boys.

Lagena globosa, Montagu, sp.

Vermiculum globosum, Montagu, 1803, Test. Brit., p. 524.

There are two distinct species of globular Lagenæ common off the Dublin coast, the apertures of which are respectively stellate and fissurine. It is the first of these, or that with the stellate aperture, which we have restricted to *L. globosa*, Mont. That with a fissurine aperture is a round form of *L. lævigata*, Reuss, which has lost its typical, depressed character, and forms a most instructive link between the round and the depressed Lagenæ. A few examples of the apiculate variety, *L. apiculata*, Reuss, Haidinger, Natwiss. Abhandl. vol. iv. pl. 1, fig. 1, were found at the entrance of Dublin harbour, 6 fathoms, and at station G.*

Lagena lineata, Williamson, sp. (Pl. XIV. figs. 13–16).

Entosolenia globosa, var. *lineata*, Williamson, 1858, Rec. For. Gr. Br., p. 9, pl. 1, fig. 17.

Shell ovate, broadest near the posterior end; surface ornamented with exceedingly delicate longitudinal lines; entosolenian, and frequently bearing an external tube, which is often bent and irregular in shape; it has also proceeding from the posterior extremity a tube, which is sometimes as long as the shell itself, but is usually broken off short. This species frequently occurs in abnormal forms. We have figured two such forms, in one of which there are no less than five separate chambers springing from a common centre.

Frequent everywhere.

* In our dredgings off the Irish coast, we have not found any examples of *L. globosa* with a simple, round aperture, as figured by Williamson and others. Such forms are, however, frequent in foreign gatherings.

Lagena lævis, Montagu, sp.

Vermiculum lævis, Montagu, 1803, Testacea Britannica, p. 524.

Frequent in nearly all the dredgings, as also the var. *clavata*, d'Orbigny, which was even more abundant than the type. *Lagena gracillima*, Seg., has been recorded in most of the Memoirs treating on British Foraminifera. We are, however, inclined to think that in many cases the specimens so called were *L. clavata*, d'Orbigny, with the neck broken off. In this imperfect condition they might be readily mistaken for *L. gracillima;* we have seen many such examples from the Dublin gatherings.

Lagena aspera, Reuss (Pl. XIV. figs. 10–12).

Lagena aspera, Reuss, 1861, Sitzungsb, d. k., Akad. Wiss. Wien., vol. xl. p. 305, pl. 1, fig. 5.

Several good typical specimens were found at Lambay, depth 45–50 fathoms. Very rare.

Some strange abnormal forms of this Lagena (Pl. XIV. figs. 11, 12) were met with off Dublin, being somewhat intermediate in character between this species and *L. sulcata*. Several examples were obtained of one of these forms (fig. 12). These specimens were made up of four or five of the Lagena in a cluster, attached at the sides, and the surface ornamented with coarse ribs; the ribs in parts being broken up into short bits, giving the shell a rudely tuberculated appearance.

Lagena hispida, Reuss.

Lagena hispida, Reuss, 1863, Sitzungsb, d. k. Akad. Wiss. Wien., vol. xlvi. p. 335, pl. 6, figs. 77–79.

Two forms of this species were met with off the Dublin coast, viz., one, typical, flask-shaped, the body ornamented with delicate hair-like spines; the other, distomous, the body roughened with short, blunt spines. Rather rare.

Lagena striata, d'Orbigny, sp.

Oolina striata, d'Orbigny, 1839, Voy. l'Amér. Mérid. p. 21, pl. 5, fig. 12.

There are two well-marked British forms of this very beautiful species, viz., an elongated form ornamented with very delicate longitudinal striæ,

which extend from one end of the shell to the other, being often more or less twisted as they pass up the neck: the other is much larger and more globular in shape, the striæ ending a short distance from the posterior extremity, where they form a ring of short, blunt spines; the neck of this variety is decussated with longitudinal and transverse striæ. This latter variety is abundant in deep water; the former is more frequent in shallow water near the coast. *L. lyellii*, Seg., we regard as a distomous variety of this species. It was found rather sparingly in several of the Dublin gatherings.

Lagena curvilineata, nov. sp. (Pl. XIV. figs. 21–24).

Flask-shaped, surface ornamented with fine curvilinear striæ. In typical examples the striæ commence from centres situated at opposite sides of the shell, round which they are twisted in the most beautifully regular manner. In some specimens the striæ cross, giving the shell a decussated appearance. This very elegant form is closely allied to *Lagena striata*. Very rare; the few examples found were nearly all from deep water in the Irish Sea.

Lagena gracilis, Williamson.

Lagena gracilis, Williamson, 1848, Ann. Nat. Hist., ser. 2, vol. i. p. 13, l. 1, figs. 3, 4.

Rare; found only at a few localities.

Lagena sulcata, Walker and Jacob (Pl. XIV. figs. 1, 2).

Lagena sulcata, Walker and Jacob, 1794 (fide Kanmacher), Adams' Essays on the Microscope, 2nd ed. p. 634, pl. 14, fig. 5.

Nearly all the Irish examples of this species which we have seen appear referable to *L. interrupta*, Will. Rec. For. Gr. Br. pl. 1, fig. 11. This form differs from the type in having the ribs of unequal length. We regard the difference as too trivial for even a varietal name. Frequent everywhere.

Lagena costata, Williamson, sp. (Pl. XIV. figs. 3–5).

Entosolenia costata, Williamson, 1858, Rec. For. Gr. Br. p. 9, pl. 1, fig. 18; Wright, 1877, Proc. Belfast, Nat. Field Club—App. pl. 4, figs. 11–14.

Generally distributed, abundant in deep water, rather rare in shallow water.

Lagena williamsoni, Alcock, sp. (Pl. XIV. figs. 6–8).

Entosolenia williamsoni, Alcock, 1864, Proc. Manchester Lit. and Phil. Soc., vol. iv No. 15; Wright, 1877, Proc. Belfast Nat. Field Club—App. pl. 4, fig. 14.

Common everywhere.

Lagena semistriata, Williamson.

Lagena semistriata, Williamson, 1848, Ann. and Mag. Nat. Hist. ser. 2, vol. i. p. 14, pl. 1, figs. 9, 10,

Frequent.

Lagena crenata, Parker and Jones (Pl. XIV. figs. 17, 18).

Lagena crenata, Parker and Jones, 1864, Phil. Trans., vol. clv. p. 420, pl. 18, fig. 4, a, b.

This is one of our rarest British Lagenæ. We only met with one specimen which was dredged in Dalkey Sound. It was not typical, the crenations being few and broad. We are indebted to Dr. Alcock, Manchester, for the very beautiful typical example which we have figured, Pl. XIV. fig. 18; it was found in a shore gathering from Dog's Bay, Connemara.

Lagena striato-punctata, Parker and Jones (Pl. XIV. fig. 20).

Lagena striato-punctata, Parker and Jones, 1867, Phil. Trans. vol. clv. p. 350, pl. 13, figs. 25–27.

This very rare Lagena was found at several localities, but we rarely got more than one or two specimens in any of the gatherings.

Lagena feildeniana, Brady (Pl. XIV. fig. 19).

Lagena feildeniana, Brady, 1878, Ann. and Mag. Nat. Hist. ser. 5, vol. i. pl. 20, fig. 4.

Only one or two specimens found; these were much more elongated in shape than the type specimen figured by Brady; they had also a basal neck and orifice somewhat similar to the basal neck and orifice in *L. lyellii*, Seg.

Lagena squamosa, Montagu, sp. (Pl. XIV. fig. 9).

Vermiculum squamosum, Montagu, 1803, Testacea Britannica, p. 526, pl. 14, fig. 2.

A very variable form, the areolæ differing greatly in shape, size and mode of arrangement. Common everywhere.

Lagena melo, d'Orbigny, sp.

Oolina melo, d'Orbigny, 1847, Voy. l'Amér. Mérid., vol. v. p. 20, pl. 5, fig. 9.

Very rare.

Lagena hexagona, Williamson, sp.

Entosolenia squamosa. var. *hexagona*, Williamson, 1858, Rec. For. Gr. Br., p. 13, pl. 1, fig. 32.

Frequent.

Lagena lævigata, Reuss, sp.

Fissurina lævigata, Reuss, 1849, Denkschr. d. k. Akad. Wiss. Wien, vol. i. p. 366, pl. 46, fig. 1 a, b.

Four well-marked forms of this species have been met with in the Dublin gatherings, viz. [1] *Lagena lævigata*, Reuss; typical, shell ovate, lanceolate, often with two mucroni at the base, common in dredgings 40–50 fathoms; trigonal examples rare. [2] Var. *lucida*, Will. Rec. For. Gr. Br., pl. 1. fig. 22. Shell compressed, pyriform, broad at the base, a bright lucid spot at either side; more depressed than the type and smaller in size; frequent in shallow water; trigonal examples rare. [3] Var. *quadrata*, Will. Rec. For. Gr. Br. pl. 1. fig. 27 (not fig. 28). Shell oblong with parallel sides, rare. [4] A fourth form was found in abundance at Lambay, depth 45–50 fathoms: shell round in cross section, and, but for its fissurine aperture, might be mistaken for *L. globosa*, Mont. It is also instructive to find occasional examples of this form with a triradiate aperture, showing the same tendency to a trigonal arrangement as the depressed forms. Common.

Lagena marginata, Walker and Jacob, sp.

Serpula (*Lagena*) *marginata*, 1874, Test. Min. p. 3, pl. 1. fig. 7; Wright, 1881, Proc. Belfast Nat. Field Club—App. pl. 8, fig. 4.

Shell depressed; periphery winged or carinate; rather rare. A few

specimens were found of a curiously modified form, one side being strongly convex, the other flat or concave; one or two trigonal examples were found with a single keel at the angles.

Trigonal examples of nearly all our British depressed Lagenæ have been found by us. We consider these as merely sports or slightly modified forms, to which no specific varietal or even subvarietal value should be attached. We have therefore excluded from the present Memoir the following hitherto recognised Lagenæ, viz.:—*L. trigono-marginata*, P. and J.; *L. trigono-oblonga* Seg.; and *L. trigono-ornata*, Brady; these we consider forms respectively of *L. orbignyana*, Seg.; *L. lævigata*, Reuss; and *L. lagenoides*, Will.

Lagena lagenoides, Williamson, sp. (Pl. XII. fig. 22).

Entosolenia marginata, var. *lagenoides*, Williamson, 1858, Rec. For. Gr. Br. p. 11, pl. 1. figs. 25, 26.

Rather rare. One or two beautiful trigonal specimens (*L. trigono-ornata*, Brady), were found in deep water gatherings.

Lagena orbignyana, Seguenza, sp.

Fissurina orbignyana, Seguenza, 1862, Foram. Monotal. Mess. p. 66, pl. 2, figs, 25, 26; Wright, 1881, Proc. Belfast Nat. Field Club—App. p. 181, pl. 8, fig. 5.

Shell depressed, tricarinate. Common everywhere. A neat, oblong variety, with parallel sides, is generally distributed around the Irish coast, but is not nearly so abundant as the typical form. Two different Lagenæ appear to be figured by Williamson under the name *L. quadrata;* (Rec. For. Gr. Br.) fig. 28 is the oblong variety just alluded to, while fig. 27 is an oblong variety of *L. lævigata*, Reuss, and is referred to in our remarks on that species. Trigonal forms (*L. trigono-marginata*, P. and J.) are rare.

Lagena castrensis, Schwager (Pl. XII. figs. 20, 21).

Lagena castrensis, Schwager, 1866, Novara Reise, Geol. Thiel, vol. ii. p. 208, pl. 5, fig. 22.

This form has hitherto been only known as a recent species from off the Australian coast, the finding of two well-marked characteristic speci-

mens in British water was therefore of great interest; the specimens were got in different dredgings, viz.: station 34, Lambay, depth 45 fathoms; and station 35, Lambay, depth 50 fathoms; and it may be of interest to state that they were found in dredged material that had been washed and floated by each of us separately.

Lagena pulchella, Brady (Pl. XII. fig. 19).

Lagena pulchella, Brady, 1866, Rep. Brit. Ass. (Trans. Sections) p. 70; 1870, Ann. and Mag. Nat. Hist. ser. 4, vol. vi. pl. 12, fig. 1.

Only three or four specimens were found; one was a trigonal form.

Lagena bicarinata, Terquem, sp. (Pl. XII. fig. 30).

Fissurina bicarinata, Terquem, 1882, Mém. Soc. Geol. France, ser. 3, vol. ii. Mém. 3, p. 31, pl. 1, fig. 24, a, b; Balkwill and Millett, 1884, Journ. Postal Micr. Soc., vol. iii. p. 14, pl. 2, fig. 4.

Shell depressed, bicarinate, with a median depression. Very rare.

Sub-family.—NODOSARINÆ.

Nodosaria, Lamarck.

Nodosaria raphanus, Linn. sp. (Pl. XII. fig. 26).

Nautilus raphanus, Linn., 1767, Syst. Nat., 12th ed. p. 1164, No. 283.

Only one specimen found.

Nodosaria obliqua, Linn. sp.

Nautilus obliquus, Linn., 1767, Syst. Nat., 12th ed., p. 1163, No. 281.

Very rare.

Nodosaria scalaris, Batsch, sp.

Nautilus (*Orthoceras*) *scalaris*, Batsch, 1791, Conchyl. Seesandes, pl. 2, fig. 4 *a*, *b*.

Frequent, generally distributed.

Nodosaria radicula, Linn. sp.

Nautilus radicula, Linn., 1767, Syst. Nat., 12th ed. p. 1164, No. 285.

Only one poor specimen found.

Nodosaria communis, d'Orbigny, sp.

Dentalina communis, d'Orbigny, 1826, Ann. Sci. Nat., vol. vii. p. 254, No. 35.

Generally distributed, but rather rare at most places.

Nodosaria consobrina, d'Orbigny, sp.

Dentalina consobrina, d'Orbigny, 1846, For. Foss. Vien., pl. 2, figs. 1–3.

Rather rare, found at a few stations in deep water.

Nodosaria pyrula, d'Orbigny (Pl. XII. fig. 23).

Nodosaria pyrula, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 253, No. 13; Soldani Testac., vol. ii. pl. 10, figs. b, c.

Generally distributed, but rare at most places. Large and beautiful specimens were found at Lambay, depth 45–50 fathoms.

Nodosaria hispida, d'Orbigny (Pl. XII. fig. 31).

Nodosaria hispida, d'Orbigny, 1846, For. Foss. Vien. p. 35, pl. 1, figs. 24, 25.

The only specimen found by us was unfortunately lost, it was from station C, off the Hen and Chickens, Isle of Man. Another example has since been found by Mr. Charles Elcock, in stuff dredged by Mr. Voysey, midway between the Isle of Man and the Mourne Mountains. We are indebted to Mr. Elcock for the privilege of figuring his specimen.

Lingulina, d'Orbigny.

Lingulina carinata, d'Orbigny.

Lingulina carinata, d'Orbigny, 1825, Ann. Sci. Nat. vol. vii. p. 257; 1839, Foram. des Canaries, p. 20, tab. 1, figs. 13, 14.

Only two specimens found.

Rhabdogonium, Reuss.

(?) *Rhabdogonium tricarinatum*, d'Orbigny, sp. (Pl. XII. figs. 17, 18).

Vaginulina tricarinata, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 258, No. 4, Modèles No. 4.

This is one of many rare things which have been met with at Lambay, depth 45–50 fathoms. It is interesting to note that the six or seven specimens found were restricted to two chambers, whilst well-grown examples of this species usually have six or seven chambers. We have therefore recorded this provisionally.

Marginulina, d'Orbigny.

Marginulina glabra, d'Orbigny (Pl. XII. figs. 24, 25).

Marginulina glabra, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 259, No. 6 Modèles No. 55.

Large, well-grown specimens of this species were found in abundance at Lambay, depth 45–50 fathoms. It was also found at a few other places; but not plentifully.

Marginulina costata, Batsch, sp.

Nautilus (Orthoceras) costatus, Batsch, 1791, Conchyl. des Seesandes, p. 2, pl. 1, figs. a–g.

Only one small specimen found.

Vaginulina, d'Orbigny.

Vaginulina legumen, Linn. sp.

Nautilus legumen, Linn., 1758, Syst. Nat. 12th ed. p. 1162.

Very rare.

Vaginulina linearis, Montagu, sp.

Nautilus linearis, Montagu, 1802, Test. Brit. Suppl. p. 82, tab. 19, fig. 6.

Very rare.

Cristellaria, Lamarck.

Cristellaria rotulata, Lamarck, sp.

Lenticulites rotulata, Lamarck, 1804, Annales du Muséum, vol. v. p. 188, No. 3.

Generally distributed, but rare everywhere.

Cristellaria cultrata, Montfort, sp.

Robulus cultratus, Montfort, 1808, Conchyl. Syst. vol. i. p. 215, gen. 54.

Very rare, specimens small and poor.

Cristellaria crepidula, Fichtel and Moll, sp.

Nautilus crepidula, Fichtel and Moll, 1803, Test. Micr. p. 107, pl. 19, figs. g–i.

Generally distributed, but rather rare at most places.

Sub-family.—POLYMORPHININÆ.

Polymorphina, d'Orbigny.

Polymorphina lactea, Walker and Jacob, sp.

Serpula lactea, Walker and Jacob 1798 (fide Kanmacher), Adams' Essays, 2nd ed. p. 634, pl. 24, fig. 4.

Frequent.

Polymorphina gibba, d'Orbigny, sp.

Globulina gibba, d'Orbigny, 1846, For. Foss. Vien. pl. 13, figs. 13, 14.

This species is so liable to variation that we hesitate to adopt the specific name, all the Dublin specimens being more or less compressed, showing a tendency to run into *æqualis*. Frequent at most localities.

Polymorphina fusiformis, Roemer.

Polymorphina (*Globulina*) *fusiformis*, Roemer, 1838, Neues Jahrb. für Min. Jahrg. 1838, p. 386, pl. 3, fig. 37.

Rare.

Polymorphina oblonga, Williamson.

Polymorphina oblonga, Williamson, 1858, Rec. For. Gr. Br., p. 71, pl. 6, figs. 149, 149a.

Frequent at many localities.

Polymorphina compressa, d'Orbigny.

Polymorphina compressa, d'Orbigny, 1846, For. Foss. Vien. p. 243, pl. 12, figs. 32–34.

Rare.

Polymorphina rotundata, Bornemann, sp.

Guttulina rotundata, Bornemann, 1855, Zeitschr. deutsch. Geol. Gesell. vol. vii. p. 346, pl. 18, fig. 3.

This form has been recently found by Mr. David Robertson, F. L. S., off the Scotch coast. It has also been found by one of us in considerable abundance in deep water off Belfast Lough. Rare in the Dublin gatherings.

Polymorphina concava, Williamson.

Polymorphina lactea, var. *concava*, Williamson, 1858, Rec. For. Gr. Br. p. 72, pl. 6, figs. 151, 152,

This interesting little parasitic form was found at a number of localities, but was usually very rare even where it occurred.

Polymorphina myristiformis, Williamson.

Polymorphina myristiformis, Williamson, 1858, Rec. For. Gr. Br. p. 73, pl. 6, figs. 156, 157.

Only a single specimen was found off the Dublin coast. It is frequent off the west coast of Ireland.

Polymorphina spinosa, d'Orbigny, sp. (Pl. XII. fig. 27).

Globulina spinosa, d'Orbigny, 1846, For. Foss. Vien. p. 203, pl. 13, figs. 23, 24.

A solitary example of this very rare species was found by Mrs. Shone in the estuary of the Dee.* It had been previously known only as a Miocene fossil. Two specimens were found in the Dublin gatherings.

Uvigerina, d'Orbigny.

Uvigerina pygmæa, d'Orbigny.

Uvigerina pygmæa, d'Orbigny, 1825, Ann. Sci. Nat. vol. vii. p. 269, pl. 12, figs. 8, 9; Modèles No. 67.

Only one or two specimens found.

Uvigerina angulosa, Williamson.

Uvigerina angulosa, Williamson, 1858, Rec. For. Gr. Br. p. 67, pl. 5, fig. 140.

Generally distributed, but rather rare at most places.

Family.—GLOBIGERINIDÆ.

Globigerina, d'Orbigny.

Globigerina bulloides, d'Orbigny.

Globigerina bulloides, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 277, No. 1; Modèles Nos. 17 and 76.

Generally distributed, but rather rare at most places.

Globigerina inflata, d'Orbigny.

Globigerina inflata, d'Orbigny, 1839, Foram. Canaries, p. 134, pl. 2, figs. 7–9.

Very rare.

* Siddall, Foraminifera of the River Dee, Proc. Chester Soc. Nat. Sci. N. S. vol. xix. p. 48.

Orbulina, d'Orbigny.

Orbulina universa, d'Orbigny.

Orbulina universa, d'Orbigny, 1839, Foram. Cuba, p. 35, pl. 1, fig. 1.

Very rare.

Pullenia, Parker and Jones.

Pullenia sphæroides, d'Orbigny, sp. (Pl. XII. figs. 28 *a*, 28 *b*).

Nonionina sphæroides, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 293, No. 1; Modèles No. 43.

Only two examples found.

Pullenia quinqueloba, Reuss, sp. (Pl. XII. figs. 29 *a*, 29 *b*).

Nonionina quinqueloba, Reuss, 1851, Zeitschr. deutsch. Geol. Gesell. vol. iii. pl. 5, fig. 31.

Only one example found. *P. sphæroides* and *P. quinqueloba* have been very rarely met with off the British coast. Both forms, however, are frequent in deep sea gatherings, and have a wide geographical distinction. They occur fossil in the chalk of the North of Ireland.

Family.—ROTALIDÆ.

Sub-family.—SPIRILLININÆ.

Spirillina, Ehrenberg.

Spirillina vivipara, Ehrenberg (Pl. XII. fig. 32).

Spirillina vivipara, Ehrenberg, 1841, Verbreitung, &c. p. 442, pl. 3, fig. 441.

Rare. A single specimen of a curiously ciliated form (Pl. XII. fig. 32), having delicate hair-like spines on the periphery, was found in Dalkey Sound, 5 fathoms.

Spirillina tuberculata, Brady.

Spirillina tuberculata, Brady, 1878, in Siddall's "Foraminifera of the Dee," Proc. Chester Soc. Nat. Sci., New Ser. vol. xix. p. 65, pl. 8, fig. 28.

We believe this to be the same shell as *S. margaritifera*, Will. Rec. For. Gr. Br. p. 93, pl. 7, fig. 204, but never having seen Professor Williamson's type specimen, we cannot speak with certainty on the subject. Very rare.

Sub-family.—ROTALINÆ.

Patellina, Williamson.

Patellina corrugata, Williamson.

Patellina corrugata, Williamson, 1858, Rec. For. Gr. Br. p. 47, pl. 3, figs. 86–88

Rare. A few specimens were found having an oval contour.

Discorbina, Parker and Jones.

Discorbina rosacea, d'Orbigny, sp.

Rotalia rosacea, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 273, No. 15; Modèles No. 38.

Frequent.

Discorbina globularis, d'Orbigny, sp.

Rosalina globularis, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 271, No. 1, pl. 13, figs. 1–4.

Common.

Discorbina orbicularis, Terquem, sp. (Pl. XIII. figs. 31–33).

Rosalina orbicularis, Terquem, 1876, Anim. sue la Plage de Dunkerque, p. 75, pl. 9, fig. 4 a, b.

Rare; in dredgings near the coast, and in shore gatherings.

Discorbina bertheloti, d'Orbigny, sp.

Rosalina bertheloti, d'Orbigny, 1839, Foram. Canaries, p. 135, pl. 1, figs. 28–30.

Very rare.

Discorbina wrightii, Brady.

Discorbina wrightii, Brady, 1881, Ann. and Mag. Nat. Hist. Ser. 5, vol. viii. p. 413, pl. 21, fig. 6 a, b, c; *D. parisiensis*, Wright (in part), 1877, Proc. Belfast Nat. Field Club, 1876–7, App. p. 105, pl. 4, fig. 2 a, b, c.

Very rare off Dublin. This species has been obtained at many places around the Irish coast. It was found plentifully in shallow water off Grey Point, Belfast Lough, as also in material dredged off Kinsale by Messrs. Thomas Wright and John Harrison.

Discorbina parisiensis, d'Orbigny, sp.

Rosalina parisiensis, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 271, No. 5; Modèles No. 38; Wright (in part), Proc. Belfast Nat. Field Club, 1876–7, App. p. 105, pl. 4, fig. 1 a, b, c, d.

Very rare.

Discorbina tuberculata, nov. sp. (Pl. XIII. figs. 28–30).

Test, trochoid, convex superiorly and inferiorly, with about two convolutions, which are visible on the superior side. The outermost convolution shows about six chamberlets. On the superior side these are separated by deeply constricted lines, and the surface of the chamberlets is roughened by a number of coarse tubercles which to a great extent obscure the septal lines. On the inferior side, the outermost convolution alone is visible. This side is usually smooth, but a few tubercles sometimes occur upon it. Aperture, a slit near the umbilicus, close to the inferior surface of the preceding convolution.

We have seen a number of examples of this small and somewhat obscure form. It may readily be distinguished from *D. globularis*, d'Orb., to which species it is most nearly allied, by its coarse tubercles, and its being very much smaller in size. Rare.

Planorbulina, d'Orbigny.

Planorbulina mediterranensis, d'Orbigny.

Planorbulina mediterranensis, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 280, No. 2, pl. 14, figs. 4–6; Modèles No. 79.

Frequent.

Truncatulina, d'Orbigny.

Truncatulina lobatula, Walker and Jacob, sp.

Nautilus lobatulus, Walker and Jacob, 1798 (fide Kanmacher), Adams' Essays on the Microscope, 2nd ed. p. 642, pl. 14, fig. 36.

Very abundant everywhere.

Pulvinulina, Parker and Jones.

Pulvinulina auricula, Fichtel and Moll, sp.

Nautilus auricula, Fichtel and Moll, 1803, Test. Micr. p. 108, pl. 20, figs. a–f.

Rare in the Dublin gatherings. This species occurs plentifully and large, off the south and west coasts of Ireland.

Pulvinulina karsteni, Reuss, sp.

Rotalia karsteni, Reuss, 1855, Zeitschr. deutsch. Geol. Ges. vol. vii. p. 273, pl. 9, fig. 6.

Very rare, specimens small.

Pulvinulina menardii, d'Orbigny, sp.

Rotalia menardii, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 273, No. 26, Modèles No. 10.

Only one or two poor specimens found.

Rotalia, Lamarck.

Rotalia beccarii, Linn., sp.

Nautilus beccarii, Linn., 1767, Syst. Nat. 12th ed. p. 1162, No. 276.

Common everywhere. A neat, thin-shelled variety approaching

R. orbicularis, d'Orb., was frequent in some of the deep water gatherings in the Irish Sea.

Rotalia nitida, Williamson, sp.

Rotalia nitida, Williamson, 1858, Rec. For. Gr. Br. p. 54, pl. 4, figs. 106–108.

Frequent.

Sub-family.—TINOPORINÆ.

Gypsina, Carter.

Gypsina vesicularis, Parker and Jones, sp.

Orbitolina vesicularis, Parker and Jones, 1860, Ann. and Mag. Nat. Hist. 3rd Ser. vol. vi. p. 31, No. 5; *Tinoporus lævis*, Carpenter, 1860, Phil. Trans. p. 559, pl. 21, figs. 1–3.

Very rare in the Dublin gatherings, and the specimens small. This interesting form is not unfrequent off the west coast of Ireland, where it often attains a large size.

Gypsina inhærens, Schultze, sp.

Acervulina inhærens, Schultze, 1854, Organ. der Polysthal. p. 68, pl. vi. fig. 12.

Only a few broken specimens found in the Dublin gatherings. This species is abundant and very fine off the west coast of Ireland.

Family.—NUMMULINIDÆ.

Sub-family.—POLYSTOMELLINÆ.

Nonionina, d'Orbigny.

Nonionina turgida, Williamson, sp.

Rotalina turgida, Williamson, 1858, Rec. For. Gr. Br. p. 50, pl. 4, figs. 95–97.

Rare.

Nonionina scapha, Fichtel and Moll, sp.

Nautilus scapha, Fichtel and Moll, 1803, Test. Micr. p. 105, pl. 19, figs. d–f.

Very rare.

Nonionina pauperata, nov. sp. (Pl. XIII. figs. 25, 26).

Shell spiral, equilateral, lenticular, revealing only the outermost convolution, which consists of about nine smooth, somewhat ventricose segments; peripheral margin angular; septal lines deeply excavated; aperture transversely oblong, close to the periphery of the preceding convolution; septal plane sagittate. Rather frequent.

Nonionina depressula, Walker and Jacob, sp.

Nautilus depressulus, Walker and Jacob, 1798, Adams' Essay, 2nd ed. p. 641, pl. 14, fig. 33.

Abundant everywhere.

Nonionina boueana, d'Orbigny (Pl. XIII. fig. 27).

Nonionina boueana, d'Orbigny, 1846, For. Foss. Vien. p. 108, pl. 5, figs. 11, 12.

Only one specimen found.

Nonionina stelligera, d'Orbigny.

Nonionina stelligera, d'Orbigny, 1839, Foram. Canaries, p. 128, pl. 3, fig. 12.

Generally distributed, but rare at most places. Immature specimens of this species often occur with a deep umbilicus; these forms are liable to be mistaken for *N. umbilicatula*, Montf.

Polystomella, Lamarck.

Polystomella crispa, Linn., sp.

Nautilus crispus, Linn., 1767, Syst., Nat. 12th ed. p. 1162.

Frequent at most localities.

Polystomella striato-punctata, Fichtel and Moll, sp.

Nautilus striato-punctatus, Fichtel and Moll, 1803, Testac. Micr., p. 61, pl. 9, figs. a–c.

Abundant almost everywhere.

Haliphysema tumanowiczii, Bowk., was found by Professor A. Haddon, off Dalkey Island, and was abundant in a small quantity of material gathered by him.

Reophax difflugiformis (?) Brady—A small, flask-shaped, arenaceous organism, apparently referable to this species, was met with in one of the Dublin gatherings, but as the only example found was broken whilst being examined under the microscope, for the present at least we consider its occurrence off the Dublin coast should be regarded as somewhat doubtful.

Miliolina venusta (?) Karrer, sp.—Shell, thin, depressed, of a long oval shape; margin bicarinate; aperture, tri-forked. Rare. The specimens were not sufficiently well grown to name with certainty; the choice however appears to be between *M. venusta*, Kar., and *M. cuveriana*, d'Orb. sp.

TABLE

OF THE

DISTRIBUTION OF RECENT FORAMINIFERA

OFF THE COAST OF DUBLIN AND IN THE IRISH SEA.

Key to localities indicated by the figures (1, 2, 3, 4, a, b, c, &c.), at the heads of the columns in the accompanying Table.

Between tides.

1. Dollymount and Clontarf.
2. Ringsend and Sandymount.
3. Booterstown and Seapoint.
4. Malahide, Portmarnock and Baldoyle.
5. Howth.
6. Sandycove and Ballybrack.
7. Dalkey Island.

Dublin Bay.

8. Off Dollymount, 4 fathoms.
9. Off Kingstown, 7 fathoms.
10. Dalkey Sound, 5 fathoms.
11. Off Dalkey, 8 fathoms.

Within 3 miles of the coast.

12. Off Ireland's Eye, 7–9 fathoms.
13. Off Ireland's Eye, 14 fathoms.
14. Off Howth Head, 18 fathoms.
15. Off Bailey L. H., Howth, 17 fathoms.
16. Between Howth and Dalkey, 13 fathoms.
17. Off Dalkey, 16 fathoms.
18. Off Dalkey Island, 18 fathoms.
19. Off Dalkey Island, 15 fathoms.
20. Killiney Bay, 8–14 fathoms.
21. Off Ballybrack Station, 12–15 fathoms.
22. Off Bray Head, 14 fathoms.

3–10 miles off land.

23. 3 miles S. of Lambay Island, 12 fathoms.
24. 4 miles E. of Howth, 13 fathoms.
25. 6 miles S.E. of Howth, 11 fathoms.
26. Kish Bank, 5 fathoms.
27. Kish Bank, 4 fathoms.
28. Off Kish Bank, 24 fathoms.
29. Off Kish Bank, 21 fathoms.
30. Off Kish Bank, 15 fathoms.
31. Off Kish Bank (Rock May), 25 fathoms.
32. Off Bray Bank, 21 fathoms.
33. Off Bray Head, 19–27 fathoms.

10–20 miles off land.

34. Lambay Deep, 45 fathoms.
35. Lambay Deep, 50 fathoms.
36. 18 miles S.E. by S. of Lambay Island, 48 fathoms.
37. 19 miles S.E. by S. of Lambay Island, 40 fathoms.

Irish Sea, Collected by Mr. Voysey.

a. Off Isle of Man, 45 fathoms.
b. Off Isle of Man, 43 fathoms.
c. Off Hen and Chickens, Isle of Man, 30 fathoms.
d. 12 miles off Carlingford, 25 fathoms.
e. Off Drogheda, 8 fathoms.
f. Off Mourne Mountains (fish's jaws).
g. 14 miles off Howth (fish's jaws).
h. 14 miles off Bray Head, 24 fathoms.
i. 8 miles off Skerries, 17 fathoms.
j. Off Drogheda, 16 fathoms; and Lambay Deep, (?) 70 fathoms—mixed.

LIST OF ABBREVIATIONS.

vr, very rare ; r, rare ; f, frequent ; c, common ; vc, very common. Species marked * are new to the British Fauna.

	Species.	Plates.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Biloculina ringens, *Lamk.*,	.. ..	r	f	f	r	..	..	r	..	vr	vr	f	f	r	vr
2	ringens, *Lamk.* var.,	Pl. xii. f. 6, 7, ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3	depressa, *d'Orb.*,	.. ..	r	r	f	vr	r	..	vr	vr	vr	vr	r	f	r	..
4	Spiroloculina limbata, *d'Orb.*,	.. ..	vr	vr	vr	vr	..	..	vr	..	r	vr	r	r	r	..
5	planulata, *d'Orb.*,	.. ..	vr	vr	..	..	..	..	vr	..	vr	vr	r	r	vr	..
6	*acutimargo, *Brady*,	Woodcut, p. 323.	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7	Miliolina trigonula, *Lamk.*,	.. ..	r	f	f	r	r	..	r	r	f	f	f	f	f	..
8	tricarinata, *d'Orb.*,	.. ..	vr	vr	vr	vr	vr	..	vr	..	..	r	..	r	vr	..
9	oblonga, *Montagu*,	.. ..	r	f	f	r	r	r	f	r	f	r	r	f	r	r
10	seminulum, *Linn.*,	.. ..	c	c	vc	vc	c	c	c	c	vc	vc	vc	vc	vc	c
11	tenuis, *Czjzek.*,	Pl. xii. f. 3–5, .	..	..	..	..	..	..	..	..	..	..	..	..	..	..
12	subrotunda, *Montagu*,	Pl. xii. f. 8, 9, .	vc	vc	vc	vc	vc	vc	vc	vr	vc	vc	vc	vr	vc	vc
13	secans, *d'Orb.*,	.. ..	f	r	vc	vc	vc	vc	vc	r	r	vc	..	f	r	f
14	bicornis, *W. & J.*,	.. ..	r	f	f	r	vr	r	c	r	r	c	c	f	r	r
15	ferussacii, *d'Orb.*,	.. ..	r	f	f	r	..	..	r	..	r	r	f	f	r	..
16	ferussacii, *d'Orb.* var., near M. sclerotica, *Karrer*,	Pl. xii. f. 10–12,	r	r	f	vr	..	..	f	..	f	r	..	..	f	..
17	pulchella, *d'Orb.*,	.. ..	..	..	..	..	..	..	..	..	vr	r	..	..	..	..
18	agglutinans, *d'Orb.*,	Pl. xiii. f. 1–3, .	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19	fusca, *Brady*,	.. ..	..	..	vr	vr	vr	..	vr	..	..	..	..	vr	vr	..
20	*Ophthalmidium carinatum, nov. sp.,	Pl. xii. f. 13–16,	..	..	..	..	..	..	r	..	..	r	..	..	r	..
21	Cornuspira foliacea, *Philippi*,	Pl. xii. f. 1, .	..	..	..	..	..	..	..	..	..	..	..	vr	..	..
22	involvens, *Reuss.*,	Pl. xii. f. 2, .	r	r	f	r	f	r	r	r	r	c	..	f	r	r
23	Technitella legumen, *Norman*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
24	Psammosphæra fusca, *Schulze*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
25	Hyperammina elongata, *Brady*,	Pl. xiii. f. 4, .	..	..	..	..	..	..	..	..	..	..	..	vr	..	..
26	Reophax fusiformis, *Will.*,	.. ..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..
27	scorpiurus, *Montf.*,	Pl. xiii. f. 5, .	..	..	..	..	..	..	..	..	..	..	..	..	..	..
28	(?) sp.,	Pl. xiii. f. 9, 22–24	..	..	..	vr	..	r	..	..	r	vr	f	r	r	..
29	Haplophragmium glomeratum, *Brady*,	.. ..	..	..	..	..	..	..	..	..	..	vr	..	r	vr	..
30	globigeriniforme, *P. & J.*,	.. ..	vr	..	r	r	vr	..	vr	r	r	r	..	f	r	vr
31	pseudospirale, *Will.*,	Pl. xiii. f. 6–8, .	..	..	..	..	..	..	..	..	..	..	..	..	..	..
32	*agglutinans, *d'Orb.*,	Pl. xiii. f. 18–20	..	..	..	..	..	..	..	..	..	..	..	..	..	..
33	canariense, *d'Orb.*,	.. ..	f	r	f	f	f	r	c	r	vc	c	f	c	f	c

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	a	b	c	d	e	f	g	h	i	j	
r	r	c	..	r	f	f	r	c	r	r	f	f	r	vr	vc	c	r	r	c	f	c	c	f	r	r	f	r	vc	1
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	c	f	..	..	..	..	..	..	..	r	..	..	..	..	2
r	r	r	r	r	f	f	r	vr	f	f	r	r	r	r	c	c	f	r	vc	vc	vc	f	f	r	f	f	r	vc	3
vr	vr	r	vr	..	vr	..	..	..	..	..	..	vr	..	vr	r	r	r	..	r	r	r	vr	vr	..	vr	..	r	r	4
..	r	r	..	..	..	vr	..	..	..	..	..	vr	..	..	r	r	..	..	vr	vr	vr	f	vr	..	..	..	r	r	5
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	vr	..	..	..	..	..	vr	..	..	..	..	..	..	6
f	f	f	r	r	r	f	..	f	r	r	..	r	r	r	r	vr	vr	vr	r	r	f	f	f	..	r	vr	f	r	7
vr	vr	vr	r	vr	r	vr	vr	..	vr	..	..	r	..	vr	r	r	..	..	r	r	r	r	..	r	r	vr	r	f	8
r	r	r	r	r	f	r	r	..	r	r	..	r	r	r	r	f	r	..	r	f	f	r	r	r	..	f	r	f	9
c	c	vc	c	c	c	vc	c	vc	f	c	c	f	c	c	vc	vc	c	c	f	c	c	c	vc	c	c	c	vc	vc	10
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	f	r	vr	..	..	..	..	..	..	f	c	r	..	..	11
vc	vc	vc	vc	vc	vc	vc	vc	vc	vc	vc	vc	vc	vc	vc	c	vc	vc	vc	vc	vc	vc	vc	vc	c	r	vc	vc	vc	12
r	f	r	vr	r	..	..	..	..	..	r	..	..	..	vr	vr	vr	vr	..	..	r	r	..	vr	..	r	r	r	r	13
f	f	c	c	r	f	c	f	c	f	c	f	c	c	c	r	f	c	c	c	vc	c	r	r	..	r	c	r	f	14
r	r	f	vr	r	f	f	..	r	r	f	r	r	r	r	r	f	f	r	c	c	f	r	r	..	..	c	r	f	15
..	vr	..	..	..	..	..	..	..	r	r	r	r	..	..	..	..	vr	..	..	vr	..	r	r	..	..	..	..	..	16
..	..	r	..	..	..	..	..	..	..	..	..	..	..	vr	vr	vr	..	..	..	..	..	r	..	..	..	..	..	..	17
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	r	..	..	..	..	r	..	18
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	r	vr	..	..	..	..	..	..	..	..	..	..	..	..	19
..	r	..	..	..	..	..	..	..	f	..	r	..	..	..	f	c	vr	f	..	vr	vr	..	..	r	vr	..	r	..	20
..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	f	f	..	..	r	..	..	r	vr	..	vr	..	..	r	21
r	r	vr	r	r	r	..	r	..	r	r	r	r	f	r	f	f	r	r	r	r	r	r	r	r	vr	f	r	f	22
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	vr	..	..	r	23
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	vr	..	..	..	..	..	..	..	..	..	..	..	..	..	24
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vc	vc	r	..	vr	..	..	f	r	..	f	..	vr	..	25
..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	r	r	c	c	vr	vr	r	26
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vc	vc	f	..	..	..	..	..	..	..	r	vr	..	..	27
vr	..	..	..	..	..	vr	vr	..	r	vr	r	r	r	r	..	r	r	vr	r	f	r	r	r	..	..	r	vr	r	28
..	..	..	..	r	..	..	..	..	r	..	..	r	..	vr	r	r	f	r	vr	r	vr	vr	..	..	..	r	vr	f	29
vr	r	vr	f	r	f	vr	vr	..	f	r	r	f	f	r	r	f	f	f	f	c	f	f	f	r	r	f	r	f	30
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vc	vc	..	..	..	..	..	c	..	..	c	..	r	..	31
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..	..	..	..	..	..	f	..	32
vc	f	c	c	c	c	r	r	..	c	c	r	c	vc	vc	r	f	f	c	f	vc	c	f	f	r	r	c	f	c	33

	Species.	Plates.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
34	Ammodiscus incerta, *d'Orb.*,	.. ..	..	..	..	..	..	..	..	..	vr	..	..	vr	vr	..	vr
35	gordialis, *J. & P.*,	.. ..	vr	vr	r	vr	..	vr	vr	..	..	r	..	vr	..	..	..
36	charoides, *J. & P.*,	Pl. xiii. f. 10.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
37	shoneana, *Siddall*,	.. ..	..	..	..	..	..	..	vr	..	..	..	..	..	vr	..	..
38	Trochamminata squamata, *J. & P.*,	.. ..	vr	vr	r	r	r	vr	c	vr	r	f	..	f	f	r	r
39	inflata, *Montagu*,	.. ..	r	..	vr	vr	vr	..	r	..	..	..	..	r	vr	..	..
40	inflata, *Montagu* var.,	Pl. xiii. f. 11, 12.	..	..	..	vr	vr	..	..	..	..	..	..	..	..	..	..
41	macrescens, *Brady*,	.. ..	vr	..	..	..	vr	..	vr	..	..	..	..	vr	..	..	..
42	Textularia sagittula, *Defrance*,	Pl. xiii. f. 15–17,	..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..
43	gramen, *d'Orb*,	Pl. xiii. f. 13, 14,	r	r	r	f	r	..	r	r	r	f	f	f	f	f	f
44	agglutinans, *d'Orb.*,	.. ..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..
45	globulosa, *Ehrenb.*,	.. ..	..	..	..	..	..	..	..	..	..	vr	..	..	..	vr	..
46	Verneuilina polystropha, *Reuss*,	.. ..	c	r	f	c	r	r	vr	..	f	c	c	f	f	f	r
47	spinulosa, *Reuss*,	.. ..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..
48	Spiroplecta biformis, *J. & P.*,	Pl. xiii. f. 21,	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..
49	Gaudryina filiformis, *Berthelin*,	.. ..	vr	vr	r	vr	vr	vr	vr	..	..	r	vr	f	r	..	..
50	Bulimina pupoides, *d'Orb.*,	.. ..	c	c	c	f	f	r	r	f	c	f	c	c	f	c	c
51	marginata, *d'Orb.*,	.. ..	r	r	r	r	r	vr	vr	r	vr	r	r	r	r	r	f
52	aculeata, *d'Orb.*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
53	ovata, *d'Orb.*,	.. ..	r	vr	f	f	f	..	f	vr	f	r	vr	f	f	r	f
54	elegantissima, *d'Orb.*,	.. ..	r	..	r	r	f	..	r	f	r	r	vr	f	r	r	f
55	subteres, *Brady*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
56	Virgulina schreibersii, *Czjzek*,	.. ..	vr	vr	r	vr	..	..	..	..	r	vr	..	r	r	..	..
57	Bolivina textilarioides, *Reuss*,	.. ..	..	..	..	..	..	..	vr	..	..	vr	..	..	r	..	vr
58	punctata, *d'Orb.*,	.. ..	r	r	f	r	f	r	r	r	r	f	r	c	f	r	f
59	plicata, *d'Orb.*,	.. ..	vr	r	f	vr	f	..	r	vr	f	f	f	c	f	r	f
60	dilatata, *Reuss*,	.. ..	..	..	..	..	vr	..	vr	..	vr	vr	vr	r	f	r	..
61	difformis, *Will.*,	.. ..	..	..	vr	..	..	..	vr	..	..	vr	..	..	vr	..	..
62	Cassidulina lævigata, *d'Orb.*,	.. ..	..	..	..	..	..	..	vr	..	vr	vr	..	r	r	..	..
63	crassa, *d'Orb.*,	.. ..	vr	..	vr	r	vr	..	vr	vr	vr	vr	r	r	r	r	vr
64	Lagena globosa, *Montagu*,	.. ..	r	c	f	f	r	r	r	..	f	r	r	c	f	f	r
65	lineata, *Will.*,	Pl. xiv. f. 13–16,	r	f	f	f	r	r	f	f	f	f	r	c	f	c	f
66	lævis, *Montagu*,	.. ..	c	f	c	f	f	f	f	f	f	f	f	c	c	f	f

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67	Lagena aspera, *Reuss*,	Pl. xiv. f. 10–12,	..	..	..	..	..	..	vr	..	vr	..	..	..	vr	..	.
68	hispida, *Reuss*,	.. ..	vr	..	vr	vr	..	..	..	..	..	..	..	vr	..	..	.
69	striata, *d'Orb.*,	.. ..	vr	vr	r	f	..	vr	vr	..	vr	vr	vr	f	f	..	.
70	*curvilineata, nov. sp.,	Pl. xiv. f. 21–24,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
71	gracilis, *Will.*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	.
72	sulcata, *W. & J.*,	Pl. xiv. f. 1, 2,	c	c	c	f	r	r	f	f	f	f	f	f	f	r	.
73	costata, *Will.*,	Pl. xiv. f. 3–5,	r	r	r	f	vr	..	vr	..	r	vr	f	r	..	..	.
74	williamsoni, *Alcock*,	Pl. xiv. f. 6–8,	c	c	c	c	f	f	c	c	c	f	c	vc	c	c	.
75	semistriata, *Will.*,	.. ..	c	f	c	f	r	vr	r	f	r	r	f	c	f	r	.
76	crenata, *P. & J.*,	Pl. xiv. f. 17, 18,	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	.
77	striato-punctata, *P. & J.*,	Pl. xiv. f. 20,	..	..	vr	vr	..	..	..	..	vr	r	..	..	vr	..	.
78	*feildeniana, *Brady*,	Pl. xiv. f. 19,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
79	squamosa, *Montagu*,	Pl. xiv. f. 9,	c	c	vc	f	r	r	f	c	c	r	f	c	c	f	
80	melo, *d'Orb.*,	.. ..	vr	vr	..	vr	..	..	..	..	..	..	..	..	..	..	.
81	hexagona, *Will.*,	.. ..	r	f	f	r	r	..	r	r	r	f	r	c	f	f	
82	lævigata, *Reuss*,	.. ..	f	c	c	f	vc	r	f	f	f	f	c	c	c	c	
83	marginata, *W. & J.*,	.. ..	vr	..	vr	vr	vr	..	r	vr	r	r	vr	f	f	r	.
84	lagenoides, *Will.*,	Pl. xii. f. 22,	..	..	vr	vr	vr	..	vr	vr	vr	vr	..	r	r	..	.
85	orbignyana, *Seg.*,	.. ..	c	c	c	f	r	r	f	r	r	f	c	c	f	c	
86	bicarinata, *Terquem*,	Pl. xii. f. 30,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
87	*castrensis, *Schwager*,	Pl. xii. f. 20, 21,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
88	pulchella, *Brady*,	Pl. xii. f. 19,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
89	Nodosaria raphanus, *Linn.*,	Pl. xii. f. 26,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
90	scalaris, *Batsch.*,	.. ..	r	vr	r	r	vr	..	vr	r	r	r	vr	r	r	..	r
91	pyrula, *d'Orb.*,	Pl. xii. f. 23,	vr	..	vr	..	..	..	vr	..	..	vr	vr	vr	r	..	.
92	radicula, *Linn.*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
93	*hispida, *d'Orb.*,	Pl. xii. f. 31,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
94	communis, *d'Orb.*,	.. ..	r	vr	r	r	..	..	vr	vr	vr	r	vr	f	r	..	.
95	consobrina, *d'Orb.*,	.. ..	..	..	..	vr	..	..	..	..	..	..	..	vr	r	..	.
96	obliqua, *d'Orb.*,	.. ..	..	..	..	..	..	..	vr	..	..	..	..	..	..	..	.
97	Lingulina carinata, *d'Orb.*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
98	(?) *Rhabdogonium tricarinatum, *d'Orb.*,	Pl. xii. f. 17, 18,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.
99	Marginulina glabra, *d'Orb.*,	Pl. xii. f. 24, 25,	vr	..	..	vr	..	..	..	..	..	..	..	..	vr	..	.

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	a	b	c	d	e	f	g	h	i	j	
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vr	vr	r	vr	r	r	vr	..	f	c	f	f	r	vr	vr	c	c	vc	vc	vc	vc	vc	vr	..	vr	..	c	r	vc	73
c	c	c	vc	c	c	c	f	r	c	c	f	c	c	c	vc	vc	vc	c	c	c	c	c	c	r	f	c	c	vc	74
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101	Vaginulina legumen, *Linn.*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
102	linearis, *Montagu*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..
103	Cristellaria rotulata, *Lamk.*,	.. ..	vr	vr	vr	r	vr	..	vr	..	vr	vr	vr	r	r	r
104	cultrata, *Montfort*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	vr	vr	..
105	crepidula, *F. & M.*,	.. ..	r	r	r	vr	vr	..	vr	vr	..	vr	r	r	..	..
106	Polymorphina lactea, *W. & J.*,	.. ..	r	r	r	r	..	..	vr	..	vr	..	vr	r	r	..
107	gibba, *d'Orb.*,	.. ..	c	f	f	f	r	r	r	f	r	r	c	c	r	r
108	fusiformis, *Roemer*,	.. ..	vr	vr	vr	r	..	..	..	..	vr	..	..	..	..	..
109	oblonga, *Will.*,	.. ..	vr	vr	vr	vr	r	..	vr	..	..	vr	r	r	vr	..
110	compressa, *d'Orb.*,	.. ..	..	..	vr	..	r	..	..	..	..	..	..	..	..	..
111	rotundata, *Bornemann*,	.. ..	..	..	..	vr	..	..	..	..	..	..	vr	..	..	..
112	concava, *Will.*,	.. ..	vr	..	vr	vr	vr	..	..	vr	vr	..	vr	vr	..	..
113	myristiformis, *Will.*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
114	spinosa, *d'Orb.*,	Pl. xii. f. 27,	vr	..	..	..	..	..	..	..	..	..	..	..	..	..
115	Uvigerina pygmæa, *d'Orb.*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
116	angulosa, *Will.*,	.. ..	r	..	f	..	..	..	r	r	r	r	r	f	f	r
117	Globigerina bulloides, *d'Orb.*,	.. ..	vr	r	r	r	r	..	r	r	f	r	..	r	r	r
118	inflata, *d'Orb.*,	.. ..	vr	..	vr	..	..	..	..	..	..	..	..	..	..	..
119	Orbulina universa, *d'Orb.*,	.. ..	vr	..	vr	..	..	..	..	..	..	..	..	..	vr	..
120	Pullenia sphæroides, *d'Orb.*,	Pl. xii. f. 28,	..	..	..	..	..	..	..	..	..	..	..	..	..	..
121	*quinqueloba, *Reuss*,	Pl. xii. f. 29,	..	..	..	..	..	..	..	..	..	..	..	..	..	..
122	Spirillina vivipara, *Ehrenb.*,	Pl. xii. f. 32,	..	..	vr	..	..	..	r	..	vr	r	..	r	r	..
123	tuberculata, *Brady*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	vr	vr	..
124	Patellina corrugata, *Will.*,	.. ..	vr	..	vr	vr	vr	..	r	..	vr	vr	vr	r	r	f
125	Discorbina rosacea, *d'Orb.*,	.. ..	r	c	c	f	r	r	r	f	r	f	f	c	f	f
126	globularis, *d'Orb.*,	.. ..	vc	c	c	c	f	f	vc	c	c	c	f	c	c	c
127	*orbicularis, *Terquem*,	Pl. xiii. f. 31–33,	vr	vr	vr	f	vr	..	vr	..	..	f	..	vr	..	..
128	bertheloti, *d'Orb.*,	.. ..	..	..	..	..	..	..	vr	..	..	r	..	vr	r	..
129	wrightii, *Brady*,	.. ..	..	..	vr	..	..	..	..	..	..	r	r	vr	..	..
130	parisiensis, *d'Orb.*,	.. ..	..	..	..	..	..	..	..	..	..	r	..	..	..	..
131	*tuberculata, nov. sp.,	Pl. xiii. f. 28–30,	..	vr	..	..	..	..	..	..	..	..	..	..	..	..
132	Planorbulina mediterranensis, *d'Orb.*,	.. ..	c	c	c	f	r	r	r	f	f	f	f	c	f	f

18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	a	b	c	d	e	f	g	h	i	j	
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	100
..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..	..	..	101
..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..	..	..	102
vr	vr	vr	r	vr	vr	..	vr	..	..	vr	..	vr	vr	vr	vr	r	r	r	r	r	r	r	r	r	f	vr	r	r	r	103
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	r	..	..	..	..	104
..	vr	..	r	vr	r	vr	..	..	..	r	vr	..	vr	..	r	f	f	r	..	r	c	f	r	r	r	r	..	r	r	105
r	r	r	r	r	..	vr	f	..	..	r	..	..	f	vr	r	f	f	r	..	..	c	c	r	f	r	..	r	r	r	106
..	r	c	f	f	r	f	c	r	vr	r	r	f	c	c	c	f	f	f	r	c	vc	vc	r	f	r	r	c	f	r	107
..	..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	vr	..	..	..	vr	f	f	..	..	r	..	..	r	..	108
..	r	vr	vr	..	vr	r	r	vr	..	r	r	..	r	..	vr	f	f	r	..	r	c	c	r	f	vr	.	f	r	f	109
..	..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..	r	vr	vr	..	..	..	..	vr	..	..	..	..	..	..	110
..	vr	vr	..	..	..	..	..	..	..	..	..	..	..	..	vr	vr	..	..	..	..	vr	vr	..	..	..	..	..	..	..	111
..	..	vr	..	..	..	..	..	..	..	..	..	..	..	..	vr	r	r	..	..	vr	vr	vr	vr	..	vr	..	r	vr	..	112
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	113
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	114
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..	vr	..	..	..	..	..	..	115
f	r	..	r	vr	vr	..	r	..	vr	r	..	..	r	r	r	f	f	r	vr	vr	..	..	f	r	f	f	r	r	r	116
r	f	r	r	r	f	r	r	r	..	..	r	..	f	r	f	f	f	r	r	f	f	f	f	r	r	r	r	r	f	117
..	vr	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	vr	vr	..	..	..	vr	vr	..	vr	..	..	..	..	..	118
..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..	..	vr	r	..	..	vr	r	r	..	..	..	..	..	..	r	119
..	..	..	..	..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..	..	120
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..	..	..	121
vr	vr	..	..	vr	..	..	vr	..	..	r	..	..	r	..	..	r	f	r	vr	vr	..	..	r	vr	..	..	..	vr	vr	122
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..	..	..	..	..	vr	vr	123
vr	vr	r	vr	r	vr	..	vr	..	vr	..	vr	..	r	vr	vr	c	f	r	r	r	vr	r	r	r	r	r	r	r	r	124
c	f	c	c	f	r	f	f	r	f	f	r	f	c	f	f	f	f	r	r	c	r	r	f	r	r	r	r	c	r	125
c	c	f	c	c	c	c	c	f	f	vc	c	c	c	vc	c	c	c	c	vc	c	vc	c	c	c	r	f	c	c	c	126
..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	127
..	..	..	r	vr	..	..	..	..	..	r	..	..	..	..	..	r	r	..	vr	..	..	..	..	..	..	..	..	..	..	vr	128
r	..	..	r	vr	..	..	r	..	..	..	..	..	..	vr	..	r	vr	..	..	..	..	..	r	..	..	..	..	r	vr	129
..	vr	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	vr	..	130
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	r	..	vr	..	..	..	..	vr	..	..	..	..	vr	..	131
f	c	f	c	f	f	f	c	r	r	f	f	r	f	c	f	f	c	r	r	f	f	c	f	c	r	r	c	r	c	132

	Species.	Plates.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
133	Truncatulina lobatula, *W. & J.*,	.. ..	vc	vc	vc	vc	f	c	vc	vc	vc	vc	vc	vc	vc	vc	
134	Pulvinulina auricula, *F. & M.*,	.. ..	vr	..	..	vr	..	..	vr	..	vr	vr	..	r	r	..	
135	karsteni, *Reuss*,	.. ..	..	..	vr	..	..	..	vr	..	..	vr	..	r	r	..	
136	menardii, *d'Orb.*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
137	Rotalia beccarii, *Linn.*,	.. ..	vc	c	c	c	f	f	f	c	f	f	c	c	f	f	
138	nitida, *Will.*,	.. ..	r	c	c	r	r	r	f	f	f	f	f	c	f	f	
139	Gypsina vesicularis, *P. & J.*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	vr	vr	..	
140	inhærens, *Schultze*,	.. ..	vr	..	..	r	..	..	r	..	..	r	..	r	r	..	
141	Nonionina turgida, *Will.*,	.. ..	..	..	vr	vr	vr	..	vr	..	vr	r	vr	r	vr	vr	
142	scapha, *F. & M.*,	.. ..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	
143	*pauperata, nov. sp.,	Pl. xiii. f. 25, 26,	r	vr	r	r	vr	vr	r	..	vr	f	vr	f	f	r	
144	depressula, *W. & J.*,	.. ..	vc	vc	vc	vc	vc	c	c	vc	vc	vc	vc	vc	c	f	vv
145	*boueana, *d'Orb.*,	Pl. xiii. f. 27,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
146	stelligera, *d'Orb.*,	.. ..	..	..	vr	vr	..	..	vr	..	vr	r	..	r	vr	vr	
147	Polystomella crispa, *Linn.*,	.. ..	c	c	c	vc	vc	vc	c	vc	c	vc	f	c	f	f	
148	striato-punctata, *F. & M.*,	.. ..	vc	vc	vc	vc	vc	vc	vc	vc	vc	f	vc	vc	c	c	vv

18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	a	b	c	d	e	f	g	h	i	j	
vc	vc	vc	vc	vc	vc	vc	vc	c	vc	vc	vc	vc	vc	vc	vc	c	vc	vc	vc	c	vc	vc	vc	vc	f	f	vc	c	vc	133
vr	..	..	vr	vr	..	..	vr	..	..	..	..	..	f	..	r	f	r	r	vr	r	r	r	vr	..	..	..	r	r	f	134
..	..	..	..	..	..	..	..	..	..	f	vr	..	vr	..	..	f	r	vr	f	..	vr	..	vr	..	f	vr	vr	..	r	135
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..	..	136
c	c	c	vc	c	c	c	c	r	f	f	c	c	c	c	c	vc	vc	c	c	c	f	c	c	c	f	c	c	vc	c	137
c	c	f	f	c	c	c	f	r	r	f	f	f	f	c	c	c	c	f	f	f	f	f	f	c	..	f	f	c	c	138
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	r	r	..	..	..	..	..	..	..	..	..	..	..	..	139
..	vr	r	vr	vr	vr	vr	r	..	..	..	..	r	vr	..	..	r	vr	r	r	vr	vr	vr	r	..	..	..	r	r	r	140
..	vr	vr	vr	r	r	..	vr	..	..	r	r	..	r	vr	r	f	f	r	r	r	r	..	f	r	f	r	vr	vr	f	141
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	vr	vr	..	..	..	r	r	vr	..	..	..	..	..	r	142
r	f	vr	r	f	r	r	r	..	..	r	r	r	f	r	f	f	c	r	r	r	r	r	r	r	r	r	r	r	r	143
vc	vc	c	vc	f	vc	vc	vc	c	f	c	c	c	c	f	c	vc	f	c	c	r	c	c	vc	vc	f	c	c	vc	vc	144
..	..	..	..	..	..	..	..	..	..	vr	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	145
vr	f	vr	r	r	vr	..	vr	..	..	..	r	..	f	vr	r	f	f	f	f	r	r	..	r	r	r	r	vr	vr	f	146
f	f	f	f	c	f	f	f	f	r	r	f	f	c	c	c	f	f	r	r	..	f	f	f	f	r	f	f	c	f	147
c	c	c	vc	vc	vc	vc	vc	f	r	vc	c	vc	vc	vc	vc	f	c	vc	vc	vc	vc	vc	vc	vc	f	c	c	vc	vc	148

LIST OF LOCALITIES, WITH PARTICULARS OF DEPTH, &c.

	Localities.	Bathymetrical Range.	Sea Bottom.	Relative quantities of material examined in pounds.	Number of Species from each Locality.
1	Dollymount and Clontarf, Dublin Bay,	Between tides.	Fine sand—several gatherings,	48	76
2	Ringsend and Sandymount, Dublin Bay,	Between tides.	Fine sand—several gatherings,	56	60
3	Booterstown and Seapoint, Dublin Bay,	Between tides.	Fine sand—several gatherings,	20	79
4	Malahide, Portmarnock, and Baldoyle, coast,	Between tides.	Fine sand—several gatherings,	42	79
5	Howth,	Between tides.	Mud and sand—several gatherings,	14	61
6	Sandycove and Ballybrack, coast,	Between tides.	Coarse sand—several gatherings,	7	36
7	Dalkey Island, rock pools,	Between tides.	Sand and sea-weeds,	7	82
8	Dollymount, 3 miles S. of,	4 fathoms.	Fine sand,	13	46
9	Off Kingstown; 30 yards E. of East Pier Lighthouse,	7 fathoms.	Mud, sand and shells,	14	71
10	Dalkey Sound,	5 fathoms.	Mud, stones and star-fish,	2	88
11	Off Dalkey; 400 yards N. of the town,	8 fathoms.	Fine sand,	13	60
12	Off Ireland's Eye; 200 yards N. E. of Martello Tower,	7–9 fathoms.	Fine muddy sand,	12	92
13	Off Ireland's Eye; ½ mile N. E. of Coastguard Station,	14 fathoms.	Mud, gravel and dead shells,	4½	87
14	Howth Head, 1 mile N. E. of,	18 fathoms.	Fine sand, sertularians and shells,	½	49
15	Off Howth; 1½ mile S. E. of Bailey Lighthouse,	17 fathoms.	Fine sand and sertularians,	21	59
16	Between Bailey Lighthouse and Dalkey,	13 fathoms.	Sand and shells,	12½	59
17	Dalkey, 2 miles N. E. of,	16 fathoms.	Mud, sand and dead shells,	4½	65
18	Dalkey Island, ½ mile E. of,	18 fathoms.	A little sand; star-fish and dead shells,	¼	60
19	Dalkey Island, 2 miles S. E. of,	15 fathoms.	Mud, sand and dead shells,	8½	77
20	Killiney Bay,	8–14 fathoms.	Sand—2 gatherings,	23½	68
21	Off Ballybrack Station,	12–15 fathoms.	Sand and shells—2 gatherings,	31½	76
22	Bray Head, 1 mile E. of,	14 fathoms.	A little mud; dead shells and star-fish,	3	68
23	Lambay, 3 miles S. of,	12 fathoms.	Fine muddy sand,	13½	70

24	Howth, 4 miles E. of,	13 fathoms.	Fine sand,	15	54
25	Howth, 6 miles S. E. of,	11 fathoms.	Fine sand,	14	63
26	Kish Bank, N. end of (9 miles off Howth),	5 fathoms.	Fine sand,	—	41
27	Kish Bank, middle of (2 miles E. of second Buoy),	4 fathoms.	Fine sand,	13½	29
28	Off Kish Bank; 3 miles of Old Kish Ship (7 mls. E. of Bailey Lighthouse),	24 fathoms.	Fine sand,	9½	70
29	Off Kish Bank; 1 mile N. of Kish Ship (new place) (Rock Migh),	21 fathoms.	Sand, scollops and sertularians,	14½ 12½	58
30	Off Kish Bank; 1 mile W. of last station,	15 fathoms.	Sand,	15	49
31	Off Kish Bank; 10 miles S. E. of Howth (Rock May),	25 fathoms.	Mud and star-fish,	6	77
32	Off Bray Bank; 2 miles N. of No. 3 Buoy,	21 fathoms.	Mud and scollops,	3½	53
33	Bray Head, 4 to 6 miles S. E. of,	20–27 fathoms.	Mud, sand, gravel and dead shells—3 gatherings,	27	73
34	Lambay Deep; 7 to 8 miles E. of Lambay Island,	45 fathoms.	Mud—several gatherings,	67	118
35	Lambay Deep, near; 13 miles E. by N. of Lambay Island,	50 fathoms.	Mud—2 gatherings,	22	108
36	Lambay Deep, near; 19 miles S. E. by E. of Lambay Island,	48 fathoms.	Mud, sand and sertularians,	22	88
37	Lambay Deep, near; 2 miles S. of last station,	40 fathoms.	Sand,	15	62
	IRISH SEA, collected by Mr. VOYSEY.				
a	Isle of Man, 14 miles S. of,	45 fathoms.	Fine sand, sertularians and broken shells,	40	82
b	Isle of Man, 15 miles S. W. of,	43 fathoms.	Sand,	21	85
c	Isle of Man; off Hen and Chickens,	30 fathoms.	Mud and fine sand,	28	82
d	Carlingford, 12 miles E. of,	25 fathoms.	Mud and fine sand,	20	96
e	Off Drogheda,	8 fathoms.	Mud and fine sand,	20	69
f	Off Mourne Mountains (taken from fish's jaws),	60 fathoms.	Fine sand,	5	78
g	Howth, 14 miles off (taken from fish's jaws),	35 fathoms.	Sand,	1½	79
h	Bray Head, 14 miles off (where "Vanguard" was lost),	24 fathoms.	Mud and fine sand,	10	75
i	Skerries, 8 miles S. W. of,	17 fathoms.	Mud and fine sand,	20	88
	Off Drogheda, 16 fathoms, and Lambay Deep, (?) 70 fathoms (mixed),	16 fms. & 70 fms.	Mud and sand,	20	95

EXPLANATION OF PLATE XII.

Figure 1. Cornuspira foliacea, Phil., 1 *a*, lateral aspect; 1 *b*, periphero-lateral aspect. × 50 diam. Lambay, 45 fathoms.

,, 2. Cornuspira involvens, Reuss, 2 *a*, lateral aspect; 2 *b*, periphero-lateral aspect. × 50 diam. Lambay, 50 fathoms.

,, 3–5. Miliolina tenuis, Czjzek, 3, 4, lateral aspects; 5, oral aspect. × 75 diam. Off Mourne Mountains (taken from jaws of a fish).

,, 6, 7. Biloculina ringens, Lamk., var. nov., 6, periphero-lateral aspect; 7, lateral aspect. × 75 diam. Lambay, 45 fathoms.

,, 8, 9. Miliolina subrotunda, Montagu, 8, lateral aspect; 9, periphero-lateral aspect. × 75 diam. Lambay, 50 fathoms.

,, 10–12. Miliolina ferussacii, d'Orb., var. near M. sclerotica, Karrer, 10, 11, lateral aspects, both sides; 12, oral aspect. × 50 diam. Killiney Bay, 14 fathoms.

,, 13–16. Ophthalmidium carinatum, nov. sp., 13, 15, lateral aspects; 16, periphero-lateral aspect. × 75 diam. Lambay, 45–50 fathoms.

,, 17, 18. (?) Rhabdogonium tricarinatum, d'Orb., 17, lateral aspect; 18, oral aspect. × 150 diam. Lambay, 45 fathoms.

,, 19. Lagena pulchella, Brady, trigonal, 19 *a*, lateral aspect; 19 *b*, oral aspect. × 100 diam. Off Drogheda, and Lambay (mixed).

,, 20, 21. Lagena castrensis, Schwager. × 100 diam. Lambay, 45–50 fathoms.

,, 22. Lagena lagenoides, Will., trigonal. × 100 diam. Lambay, 45 fathoms.

,, 23. Nodosaria pyrula, d'Orb, × 25 diam. Lambay, 45 fathoms.

,, 24, 25. Marginulina glabra, d'Orb. × 25 diam. Lambay, 45 fathoms.

,, 26. Nodosaria raphanus, Linn. × 25 diam. Lambay, 45 fathoms.

,, 27. Polymorphina spinosa, d'Orb. × 100 diam. Dollymount, between tides.

,, 28. Pullneia sphæroides, d'Orb., 28 *a*, lateral aspect; 28 *b*, periphero-lateral aspect. × 100 diam. 6 miles S.E. of Howth, 11 fathoms.

,, 29. Pullenia quinqueloba, Reuss, 29 *a*, lateral aspect; 29 *b*, periphero-lateral aspect. × 100 diam. Lambay, 45 fathoms.

,, 30. Lagena bicarinata, Terquem, 30 *a*, lateral aspect; 30 *b*, oral aspect. × 100 diam. 14 miles off Howth (taken from jaws of a fish).

,, 31. Nodosaria hispida, d'Orb. × 50 diam. 30 miles E. of Mourne Mountains, 75 fathoms. In the collection of Mr. Charles Elcock.

,, 32. Spirillina vivipara, Ehrenb., hispid. var. × 100 diam. Dalkey Sound, 5 fathoms.

A.T. Hollick lith.

West, Newman & Co imp

EXPLANATION OF PLATE XIII.

PLATE XIII.

Figure 1–3. Miliolina agglutinans, d'Orb., 1, 2, lateral aspect, both sides; 3, oral aspect, × 75 diam. Off Kingstown, 7 fathoms.

„ 4. Hyperammina elongata, Brady, 4 *a*, lateral aspect; 4 *b*, oral aspect. × 25 diam. Lambay, 45 fathoms.

„ 5. Reophax scorpiurus, Montf., 5 *a*, lateral aspect; 5 *b*, oral aspect. × 25 diam. Lambay, 45 fathoms.

„ 6–8. Haplophragmium pseudospirale, Will., 6, 7, lateral aspects; 8, oral aspect. × 25 diam. Lambay, 45 fathoms.

„ 9. (?) Reophax sp. × 50 diam, 10 miles S.E. of Howth, 25 fathoms.

„ 10. Ammodiscus charoides, P. and J., 10 *a*, lateral aspect; 10 *b*, periphero-lateral aspect. × 150 diam. Off Kish Bank, 24 fathoms.

„ 11. Trochammina inflata, Montagu, var. nov., 11 *a*, superior lateral aspect; 11 *b*, inferior lateral aspect. × 150 diam. Off Drogheda, 16 fathoms.

„ 12. Trochammina inflata, Montagu, var. nov., 12 *a*, superior lateral aspect; 12 *b*, inferior lateral aspect. × 150 diam. Killiney Bay, 8–14 fathoms.

„ 13, 14. Textularia gramen, d'Orb., 13, lateral aspect; 14, periphero-lateral aspect. × 25 diam. Lambay, 45 fathoms.

„ 15–17. Textularia sagittula, Defrance, 15, 16, lateral aspects; 17, periphero-lateral aspect. × 25 diam. Off Ballybrack Station, 15 fathoms.

„ 18–20. Haplophragmium agglutinans, d'Orb., 18, 19, lateral aspects; 20, oral aspect. × 75 diam. Off Skerries, 17 fathoms.

„ 21. Textularia (Spiroplecta) biformis, P. and J. × 100 diam. Off Drogheda, 8 fathoms.

„ 22. (?) Reophax sp. × 50 diam. Off Skerries, 17 fathoms.

„ 23. (?) Reophax sp. × 50 diam. Off Ireland's Eye, 7–9 fathoms.

„ 24. (?) Reophax sp., end view. × 50 diam. 6 miles S.E. of Howth, 11 fathoms.

„ 25, 26. Nonionina pauperata, nov. sp., 25, lateral aspect; 26, periphero-lateral aspect. × 100 diam. Lambay, 45 fathoms.

„ 27. Nonionina boueana, d'Orb., 27 *a*, lateral aspect; 27 *b*, periphero-lateral aspect. × 75 diam. Off Kish Bank, 24 fathoms.

„ 28–30. Discorbina tuberculata, nov. sp., 28, superior lateral aspect; 29, inferior lateral aspect; 30, periphero-lateral aspect. × 150 diam. Lambay, 45 fathoms.

„ 31–33. Discorbina orbicularis, Terquem, 31, superior lateral aspect; 32, inferior lateral aspect. × 75 diam. Dalkey Sound, 5 fathoms; 33, periphero-lateral aspect. × 75 diam. Dollymount, between tides.

1
2
3
4 a
4 b
5 a
5 b
6
7
8
9
10 a
10 b
11 a
11 b
12 a
12 b
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27 a
27 b
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EXPLANATION OF PLATE XIV.

PLATE XIV.

All the Figures on this Plate are enlarged 100 diameters.

Figs. 1, 2. Lagena sulcata, W. and J., 1, lateral aspect; 2, oral aspect. Lambay, 50 fathoms.

,, 3, 4. Lagena costata, Will., 3, lateral aspect; 4, oral aspect. Lambay, 50 fathoms.

,, 5, Lagena costata, Will., bilocular. Lambay, 50 fathoms.

,, 6, 7. Lagena williamsoni, Alcock, 6, lateral aspect; 7, oral aspect. Lambay, 50 fathoms.

,, 8. Lagena williamsoni, Alcock, bilocular. Lambay, 45 fathoms.

,, 9. Lagena squamosa, Montagu, bilocular. Dalkey Sound, 5 fathoms.

,, 10. Lagena aspera, Reuss. Lambay, 45 fathoms.

,, 11. Lagena aspera, Reuss, abnormal. Lambay, 45 fathoms.

,, 12. Lagena aspera, Reuss, abnormal. Off Drogheda, 16 fathoms.

,, 13, 14. Lagena lineata, Will. Lambay, 50 fathoms.

,, 15, 16. Lagena lineata, Will., abnormal. Lambay, 50 fathoms.

,, 17. Lagena crenata, P. and J., form with very few crenations. Dalkey Sound, 5 fathoms.

,, 18. Lagena crenata, P. and J. (typical form). Dog's Bay, Connemara, between tides. In the collection of Dr. Alcock.

,, 19. Lagena feildeniana, Brady. Lambay, 45 fathoms.

,, 20. Lagena striato-punctata, P. and J. Dalkey Sound, 5 fathoms.

,, 21. Lagena curvilineata, nov. sp. Lambay, 50 fathoms.

,, 22, 23. Lagena curvilineata, nov. sp. Off Mourne Mountains (taken from jaws of a fish).

,, 24. Lagena curvilineata, nov. sp. Lambay, 45 fathoms.

A.T. Hollick lith.
West, Newman & Co imp

XIX.—Report *on the Botany of Sinai and South Palestine.* By H. C. Hart, B. A. (Plates XV., XVI., and XVII.)

[Read, February 23, 1885.]

I.—Introductory.

Early in the summer of 1883, my friend, Professor Hull, Director of the Geological Survey of Ireland, proposed that I should accompany him as a volunteer on a geological and surveying expedition to Sinai and Palestine, of which he was about to take charge, under the auspices of the Palestine Exploration Society.

With the main object of studying the botany of this region I accepted this friendly offer. I was chiefly induced to do so by the assurance I received from Professor Oliver, of Kew, that whatever our Continental brethren may have accomplished, few British botanists had as yet turned their attention to Sinai. He at the same time promised his valuable assistance in the determination of my specimens upon my return—a promise since fulfilled in a manner which entitles him to my sincerest thanks. Another welcome consideration which helped to determine me was that of a grant of money from the Scientific Fund of the Royal Irish Academy.

I beg to tender here my warmest acknowledgements to Mons. Edmond Boissier, the eminent botanist of Geneva, author of the invaluable "Flora Orientalis." He has kindly determined for me some of the more intricate genera, which his unrivalled knowledge and extensive Oriental herbarium enabled him to deal with satisfactorily.

For further information I refer the reader to the above-mentioned work; also to the Ordnance Survey of Sinai, published in 1869, where an appendix on this subject will be found, as well as copious other matter relative to Sinai. An interesting Paper by Mr. Redhead on the Flora of

Sinai, in the Journal of the Linnean Society for 1867 (Botany, vol. ix.), may also be referred to, although his specific names must in some instances be received with caution. Decaisne's "Florula Sinaica," published in the *Annales des Sciences Naturelles*, 1836, must also be referred to; and for a description of the general characters of the Desert Flora the reader should turn to a Paper by Dr. Anderson, in the "Proceedings" of the Linnean Society for 1860. (Supplement to vol. v.)

On the botany of Palestine the latest publication is that excellent work the "Fauna and Flora of Western Palestine," by Canon Tristram. Ascherson, Post, Barbey, and others, have recently laboured here, and the Flora of Western Palestine may be looked on as fairly well made known.

I must not omit to acknowledge here the judicious and kindly guidance by which (with the assistance of our most efficient interpreter and conductor, Bernard Heilpern, of Jerusalem) Professor Hull brought our travels to a safe conclusion. In a volume just published by the above-mentioned society he has given the public an account of our experiences, as well as his own leading scientific results; and to it and its appendix, by our surveying companion, Major Kitchener, the reader may turn for geographical, geological, and other information.

In the following pages I propose, in the first place, to give a general account of the botanical collection made in the order in which they were gathered, with such extracts from my journal as may serve to illustrate them. Afterwards I will enumerate in their proper order the various species which have been identified, giving, where desirable, the localities in which they were found.

II.—Ain Musa to Wady Lebweh.

Having left Suez on Saturday, November 10, 1883, we took up our quarters till Monday at Ain Musa, the usual starting-place for Sinai and the north-west corner of the peninsula. With the exception of a couple of showy flowering shrubs, Lantana camera, L., and Cassia bicapsularis, in the little gardens of date palms, and esculent vegetables bounded by fences of the prickly pear (Opuntia), there was hardly a vestige of unwithered

vegetable life. In view of the advanced season my hopes had been at a low ebb, and my first attempt at collecting was not reassuring. Matters improved, however, as we ascended above sea level.

Closer inspection about these wells yielded several identifiable species, to which ripe seed-vessels were usually adhering. Ceratophyllum demersum, Linn., was found drifting in the gulf, probably derived from the canal. Like most other aquatics, the hornwort has a very wide range, and is known to occur in Egypt. A very prickly prostrate grass in the sandy stony flat between the wells and the Gulf of Suez has been named for me by Mons. Boissier, Sporobolus spicatus, Vahl. This species is also found in Egypt, but not hitherto in Sinai.

In these enclosures, and around their edges, were bushes of tamarisk and ghurkud, Tamarix nilotica, Ehr., and T. articulata, Vahl. (?); Nitraria tridentata, Desf. The latter is a glaucous spiny bush, with small reddish-yellow berries and succulent leaves, and greedily eaten by camels. It belongs to the Zygophylleæ or 'bean-caper' family, which is well represented in the desert of Sinai by six genera.

After a day or two, when my Bedouin camel-driver had discovered which of us two was master, I usually travelled on foot, letting him keep me in view till wanted. For this interesting and faithful son of the desert, Khalîl by name, I conceived a great affection. I may mention that this feeling is frequently indulged in towards the Arabs by inexperienced Eastern travellers.

As fast as I made gatherings I was then able to deposit them on the back of my admirable beast of burthen. For this purpose I had two sets of camel-bags and drying-boards, as well as multifarious swinging gear; gun, spy-glass, water-bottle, spirit cylinder, portfolios, insect boxes, and shoulder-bags.

The country traversed was of gravel and sand, with occasional outcrops of limestone. This limestone sand is here often finely and regularly granulated, as at Wady Sudr, a condition not observed in other parts of Sinai. Our direction lay nearly parallel to the Gulf of Suez, gradually widening the distance between us and the coast-line. The view across this arm of the Red Sea, to the Jebel Rahah mountains, was superb. The sky was of a

brilliant blue, and the temperature was not hot enough to be disagreeable.

The plants gathered at Wady Sudr were—Zilla myagroides, Desf.; Retama rœtam, Forsk.; Alhagi maurorum, D. C.; Acacia seyal, Del.; Deverra tortuosa, Gærtn.; Anabasis articulata, Forsk.; Reaumuria vermicularis, Linn.; Fagonia glutinosa, Boiss. et vars.; Erodium glaucophyllum, Ait.; Citrullus colocynthis, Schr.; Artemisia judaica, Linn.; Odontospermum graveolens, S. Bip.; Gymnocarpus fruticosus, Pers.; Paronychia desertorum, Boiss.; Œrua javanica, Juss.; Heliotropium luteum, Pers.; Aristida obtusa, Del. Most of these are strictly desert species of continual occurrence in the lower parts of the peninsula, and need seldom again be referred to. In Wady Sudr, Farsetia ægyptiaca, Turr, and Anabasis setifera, Moq., were also obtained.

Of these, Zilla is a pretty pink-flowered glaucous shrub, food for camels, and not much unlike our Cakile. It was found in flower later at the Dead Sea. The Retama is an almost leafless broom, about eight feet high on an average, with fragrant purple and white flowers. It is the juniper of the Scriptures, and abundant in the desert region. Alhagi, a low spiny leguminous plant, is said to furnish a great part of the so-called "Manna of Sinai," a sort of sugary gum, prepared into confectionery, which exudes and hardens on the stem. Deverra is one of the very few characteristic desert umbellifers, a wiry fennel-smelling leafless plant. Anabasis, or Salsola, is perhaps the most abundant species throughout; a grey-branched leafless plant, often reaching a good height; and where desert Helices occur it is covered with them. It is more a native of the Syrian and Mesopotamian deserts than those further south. Fagonia is one of the most variable and multiform genera met with. All the forms are referred by Anderson to the one European species, F. cretica, Linn. Citrullus, the desert gourd, a trailing plant, with an orange-coloured fruit about the size of a mandarin orange, is the well-known colocynth, the coloquintada of Shakespeare, whose purgative properties are not unknown to the Arabs. The Aristidæ are beautiful feathery-awned grasses, and the Œrua is a woolly, felted-leaved amarant. The Acacia is one of the spiniest bushes of the desert, with a habit not unlike that of our hawthorn.

The desert flora of which these are examples has many peculiar characteristics, which soon become familiar. Its members have usually a whitened appearance, no doubt enhanced sometimes by the advanced season of my visit. This is due to woolliness, or scalyness, and is frequently accompanied by heavy odours and succulent or glaucous foliage. Spines, prickles, hooked or clinging hairs, are also characteristic; and the whole plant is not unfrequently found to be bathed in some strong gummy exudation. The odours are often aromatic, as in Santolinæ and Artemisiæ of the desert, and in most of the labiates of the higher region; but in the desert plants they are frequently powerfully nauseous, as in Peganum, Haplophyllum (Ruta), Odontospermum, and others.

The flora of which the above are the characteristics is perhaps most remarkable on account of its vast range. From Senegal, the Canaries, and the Cape de Verdes on the west of Africa, it reaches across the broad belt of Africa, south of the Morocco and Algerian mountains, inhabiting the Sahara and Libyan desert, Egypt to Nubia, and thence across Arabia Petræa, and the whole of the Arabian peninsula, except the highest mountains, to the Persian Gulf. By southern Persia it continues through Beloochistan to Sinde and the Punjaub in north-western India. Several of the above species have this enormous range in an unaltered condition. A few have outlying habitats in the south-west corner of Spain, and one or two others in Cyprus, Crete, and Greece.

Of the Sinaitic mountains we had not as yet obtained a view; we were, however, gradually rising above sea level, and with the cooler atmosphere there was a steady increase also in the quantity of vegetation. A very fragrant bushy Artemisia, A. (Santolina) fragrantissima, Linn., had become frequent, and was subsequently one of the most characteristic plants of the flat wadies.

In Wady Sudr Cleome arabica, Linn., Pennisetum dichotomum, Del., and Elionurus hirsutus, Vahl., were secured in good condition. The latter two grasses are much desired by the camels, who rarely leave specimens for the botanist. The Cleome, a clammy capparid, with small purple flowers, and pods an inch long, is a typical, though local, desert species. The Anabasis has its dried twigs always topped by a few scales, the

remains of the floral envelope. These are occasionally a showy red or claret colour, and give a brilliant effect. Next to it, Gymnocarpum, a plant of the Paronychieæ order, is perhaps the commonest desert species. Its order is well represented in the desert.

The Anabasis and Tamarisk accumulate heaps of sand around their roots, in which small rodents and lizards burrow in great numbers. The vegetation is scattered in tufts amongst the sand and gravel: except in the occasionally moistened wady beds, these tufts are usually isolated and often far apart.

On the 13th, at about 350 feet above sea level, we entered a bed of chalk, intermixed with white marls, strewed chert, selenite, and cretaceous fossils. We reached Wady Ghurundel ("Elim") by moonlight. Tamarisks and palms (Phœnix dactylifera, Linn.) form here a pleasant grove. Zilla, Nitraria, and most of the species already mentioned, were plentiful.

The rock here is a white cretaceous limestone. The bed of the wady is cut deeply in marl deposits, leaving sheer mud banks sometimes eight or ten feet high. The bed of this periodic stream was now perfectly dry. These deposits, and those in other places, lead to the conclusion that there was a greater rain-fall in recent times. On this subject Professor Hull has given us much information.

Several plants were here first met with. One of the most conspicuous was a shrubby mignionette, Ochradenus baccatus, Del., thenceforward common in the lower desert wadies, and, where protected by acacia bushes from the camels, six or eight feet high. Between this and Wady Useit I first noticed Acacia tortilis, Hayne, less spiny, and usually larger and more upright than A. seyal, L., and differing from it in structural peculiarities. These two acacias were the only ones I met in the peninsula; but another, A. nilotica, Del., has been found there. Later on I found a much finer acacia, A. læta, R. Br., at the south end of the Dead Sea.

Other species were: Cucumis prophetarum, Linn.; Polycarpæa fragilis, Del.; P. prostrata, Dcne.; Zygophyllum album, Linn.; Fagonia arabica, Boiss.; Lithospermum callosum, Linn.; Cressa cretica, Linn.; Euphorbia cornuta, C. & D.; Juncus maritimus, Linn. β. arabicus; Typha augus-

tata, B. & C.; Cynodon dactylon, Pers.; Phragmites communis, Linn., var. gigantea. This form of our reed, which reaches a height of ten or twelve feet with its erect plume of feathery inflorescence, is a truly handsome grass. It appears to have frequently done duty for Arundo donax Linn., which I did not see in Sinai.

Many withered chenopods occurred here, the identifiable species being Suæda vermiculata, Forsk.; Atriplex leucocladum, Boiss.; A. halimus, Linn., Anabasis setifera, Moq.; and the ubiquitous A. (Salsola) articulata, Forsk.. At Wady Useit occurred a little grove of date palms, some of them perhaps fifty feet high. Only one other palm, the "doum" palm, Hyphæne thebaica, Del., inhabits Sinai. It occurs at Akaba and at Tor.

Nature rests herself in the desert almost as thoroughly as in an arctic winter. In the latter case, she sleeps during an excessive cold; in the former, her strength is exhausted during an extreme heat. Nevertheless, many late-flowering plants still occasionally held their petals together, and ere many days the first harbingers of spring appeared. Possibly these should be called hybernal.

Our direction was still mainly south-east, and steadily rising. At the head of Wady Humr, about 1300 feet above sea level, we obtained our first view of the Sinaitic Mountains. Jebel Serbal stood out grand and rugged straight ahead of us, looking about one half of his real distance off, so excessively clear was the atmosphere.

Leyserra capillifolia, D. C., a slender filiform-stemmed composite, was here first met with, and the favourite camel grass Elionurus (Cælorrhachis) hirsuta, Vahl., was found in flower.

Having left Wady Humr, and crossed Sarbut el Jemel at about 1700 feet above sea level, we came out on a wide sandy plain which covers about thirty square miles. This was Debbet er Ramleh, lying at about 1700 to 1850 feet above sea level. It is the largest expanse of sand in Sinai. Some interesting plants were here first seen. The two species of Polycarpæa, with their slender trailing stems and small stellate flowers with the sticky Cleome, abounded. Seetzenia orientalis, Dcne.; Glinus lotoides, Linn., not in flower; Monsonia nivea, Dcne.; Pancratium sickenbergeri, A. & S.; Danthonia forskahlii, Linn.; and another Aristida, A. plu-

mosa, Linn., even prettier than the one already gathered. Monsonia is a beautiful little cranesbill, with silvery-white entire heart-shaped leaves. Seetzenia is a trailing yellow-flowered zygophyllaceous species, with a remarkable ovoid little capsule dehiscing in longitudinal strips. Of these, however, the white and perfect little Pancratium was the greatest prize. I secured many bulbs here and elsewhere. It is a lovely Eucharis-like flower, and as yet without leaves, although in some cases the fruit was ripening. This species was first discovered by Sickenberger, near Cairo, some years ago.

At a slightly lower level near this, Lycium europæum, Linn., afterwards common, was first met with. It was in full flower, and visited by a small copper butterfly, an order of which very few were met with.

In Wady Nusb several fresh species occurred. Unrecognisable fragments awoke vain regrets at the season selected from time to time. The following were determined: Morettia canescens, Boiss.; Astragalus sieberi, D.C., A. trigonus, D.C. (?); Crotalaria ægyptiaca, Bth., and Convolvulus lanatus, Vahl. These are very noteworthy and characteristic forms. The Astragals were quite withered, and were simply well-rooted branches of strong sharp spines, two to three inches long, set closely round a little stump of a rooted stem. These spines were the indurated midribs of the pinnate leaves. The only evidence of their earlier condition lay in the slight cicatrices on the spines at regular intervals, marking the points of attachment of the fallen leaflets. Of the Convolvulus, a handsome velvety-white, erect species, I obtained a couple of good-sized reddish purple flowers.

Farsetia ægyptiaca, Turr., a crucifer nearly allied to Matthiola, was very common and in flower.

In Wady Nusb there is a well, and quite a goodly show of acacia bushes, chiefly of the species A. tortilis, Hayne, which was somtimes in flower and usually in leaf. Its bark is commonly reddish. The leaf segments of this acacia are larger and fewer than those of A. seyal; the pods are twisted, and the tree attains a greater size. It is less spiny, and on one occasion when I had to climb for a bird this difference was thoroughly well appreciated.

In this wady I gathered Malva rotundifolia, Linn., and Amarantus

sylvestris, Desf., both probably introduced by human origin. The former is eaten by the Bedouins. Lycium has flowers either white or pinkish. Other species met here first were Dæmia cordata, R. Br.; Echiochilon fruticosum, Desf.; Lavandula coronopifolia, Poir.; Crozophora obliqua, Vahl.; and Zizyphus spina-christi, Linn. The latter was in cultivation, and occurred in a miserable little enclosure by a Bedouin's hut at the well. It was less thorny than the native "Nubk," afterwards gathered, and the fruit somewhat larger, being no doubt slightly altered by cultivation. Dæmia was the first asclepiad met with, an order characteristic of hot countries, and of which several genera occur in Sinai. This one trails on the ground usually for want of better support, and has a thick, clammy, milky juice, very plentiful in its entire leaves.

As we were gradually increasing our elevation amongst the wadies derived from the southern precipitous escarpment of the Tih plateau (4000 to 5000 feet), so there were increasing remains of last summer's vegetation, later in flowering, perhaps, and less scorched than the same species below.

Soon after leaving Wady Nusb, where we occasionally crossed belts of a bright red sandstone, we entered on a plutonic formation, a red porphyritic granite, which was henceforth to carry us upwards and over a large extent of country. The increased quantity of acaciæ, since we left the limestone, and especially on the granite, is noteworthy. Its ferocious spines may require an admixture of silicon to give them the necessary hardness.

Having crossed an elevated granitic ridge, Ras Suwig, at about 2400 feet above sea level, from whence Jebel Serbal afforded a magnificent prospect, we descended into a wady which yielded several fresh species. The Pancratium was found here again. A small bulb, apparently an Allium, was brought to me by some Bedouins; probably A. sinaiticum, Boiss. It is growing now with many other bulbs, under Mr. Burbidge's care, at the Trinity College Gardens, but has not yet flowered. These two bulbs and a Uropetalum are, I believe, the only ones which can support life in this desert. A few others occurred, but at sufficient heights, usually very considerable, to bring them into a different climate.

At the height of 2200 to 2400 feet above sea level the following species

appeared: Iphiona juniperifolia, Cass.; Sonchus spinosus, Del., and a very fetid rue, Ruta tuberculata, Forsk., a small species with yellow flowers. The other two are bushy yellow composites, the latter with a remarkably zigzag habit in its spiny branches.

Capparis galeata, Fres., a large form of the European caper, was also obtained here. Mons. Boissier ranks it as a species.

In Wady Khamileh, two desert species occurred in some quantity, Lotononis leobordea, Linn., and Pulicaria undulata, D. C. It is to be understood that, unless the contrary is afterwards stated, most of these species, although not repeated by name, were frequently met with.

The felted Œrua was laden with tassels of wool, the remains of its withered florescence. A variety, with narrower leaves and more rigid habit, was first gathered here. Acacia seyal still occurred: it is a revelation of spinosity, whose branches even camels only nibble with care. It is usually a low, flat-topped bush, often only four or five feet high, but with a considerable trunk.

A Matthiola, probably M. arabica, Boiss., occurred; and a large cabbage-leaved, sticky Hyoscyamus, H. muticus, Linn., with showy veined flowers, was pointed out to me as the "sekkaran," which the Arabs are said to inhale as an intoxicant in their narghilis. I had met it before near Wady Ghurundel.

III. Wady Lebweh to Mount Sinai.

Still ascending gradually up Wady Lebweh, from 2500 to 3500 feet, many interesting Sinai plants were gathered. Most of these are true desert species, which extend upwards about thus far; but they had begun to be mixed with others of an intermediate elevation between desert and plateau, which about corresponds with the Mediterranean and Mesopotamian floras. Several true plateau plants began to occur. From this Wady, I collected Glaucium arabicum, Fres.; Caylusea canescens, St. Hil.; Cleome trinervia, Fres.; Fagonia myriacantha, Boiss.; Tribulus terrestris, Linn.; Peganum harmala, Linn.; Neurada procumbens, Linn.; Santolina fragrantissima, Forsk.; Artemisia herba-alba, Asso., et var. laxiflora, Sieb.; Anarrhinum pubescens, Fres.; Trichodesma africanum, R.Br.; Heliotropium

undulatum, Vahl.; Gomphocarpus sinaicus, Boiss.; Ballota undulata, Fres.; Teucrium polium, Linn., *β.* sinaicum.; Stachys affinis, Fres.; Primula boveana, Dcne.; Acanthodium spicatum, Del.; Forskahlea tenacissima, Linn.; Andrachne aspera, Spr.; Asphodelus fistulosus, Linn. var., and others too damaged to name. The labiates in the above group were indications of our approach to the upper region of Sinai. The Primula is peculiar to the peninsula.

On the summit of Zibb el Baheir, at 3890 feet, a point which all travellers should climb for the sake of the really splendid view, Gypsophila rokejeka, Del.; Helianthemum lippii, Pers.; Iphiona montana, Vahl., and a Poa, P. sinaica, St. (?), were collected. A Psoralea occurs here also, but was not found in a recognizable condition. It may prove to be P. plicata, Del.

Of the plants just enumerated, several are peculiar to Sinai. Others, believed endemic, I found later on at Mount Hor in Edom. It is to be remembered that the majority of the earlier species still occurred. The chief failures are in the families Zygophylleæ and Salsolaceæ, except Anabasis. Cleome arabica had also ceased. The variable but always pretty little Fagonia is continually arresting attention by some new deviation. Sometimes it is glabrous, sometimes viscid; sometimes very leafy, with trifoliate or undivided leaves; at others, a bunch of twigs or thorns, trailing or suberect; while the flowers vary much in size, but are always of the same true pink colour. In one form or another, it is a widespread desert species, which has received a variety of segregational names.

The abnormal Neurada procumbens, with its curious, flat, prickly-edged capsules, nearly an inch in diameter, was in good condition, but scarce. It has, after many changes, been referred to the Rosaceæ. I think I am right in stating that this plant has the property of rooting its seeds in the sand without discharging them from the capsule.

Gomphocarpus was in full flower and fruit. Like Dæmia, it has a thick, staining, milky juice, according to the Bedouins, very poisonous. Besides these two Asclepiads, five other genera, each represented by a single species, occurred in the peninsula. Artemisia herba-alba, in several distinct forms, was henceforth one of the most abundant and highly aromatic plants.

From Zibb el Baheir, which I ascended with Dr. Hull on Sunday, the 19th November, we obtained a splendid view of the whole mass of Jebel Musa (Mount Sinai), and Jebel Catharine, on the south-east end of Serbal, nearer us to the southward. In Wady Berah, the stony margins of water-courses were often gay with the above composites and labiates. A little further was a continuous grove of retem bushes, the first bit of extravagance in vegetation I had seen, except close to the widely-separated wells and springs. This wady, like most others, is of considerable width, with a faintly-marked channel wandering from side to side, and marked by a line of greyish green growth, which is, no doubt, much more pleasing when viewed soon after rain.

The mountains are of red porphyry, intersected by numerous dykes of darker coloured trap. This is surely the proper country for a geologist to come to: no annoying mantles of soil or vegetation conceal the rock masses; all is bare and clear, and a good view reveals as much as a shire-full of well-borings and railway-cuttings.

The temperature had become much colder. The thermometer fell to within four or five degrees of freezing point at night. At breakfast, in the dark, we were cold and miserable; when the sun was up the day was warm and delicious.

Acacias became rare or absent at about 3500 feet. They may be taken to mark the vertical limits of the typical desert flora, as the date-palm does its geographical distribution. The desert species which exceed this vertical limit will be found to be mostly Syrian or Mesopotamian species, such as Alhagi, Artemisiæ, Anabasis, and not those properly belonging to the flora already described.

In Wady es Sheikh, some large tamarisk bushes, T. nilotica, occurred, of about fifteen feet in height. The vertical range of this tamarisk is probably about equivalent to that of the Acacia. This tamarisk is one of the many sub-species which would be placed by some under T. gallica. United, the species will possess a range from England across South Europe, Africa, and Arabia, to Persia and Turkestan. Like many other wide-ranging desert species, as various Salsolæ, its chief requirement is saline soil.

The Wady es Sheikh is of considerable length, upwards of twenty miles

running east at first, and then south, to the base of Jebel Musa. It lies high, from 3000 to 4000 feet, and in some places is girded by noble walls of cliff. Its chief plants are Artemisiæ, Santolinæ, and Zilla, except on its northern side, at the base of whatever shelter from the sun there may be. Here many of the species enumerated still occurred. Some appeared, which had not been seen lately, and were more local, as Zygophyllum album, Linn.; Nitraria tridentata, Desf.; Alhagi maurorum, D.C.; Lotononis leobordea, Linn.; Euphorbia cornuta, D. C.; Crozophora obliqua, Vahl.; Pancratium sickenbergeri, Asch. et Sch., and the labiates and composites of Wadies Labweh and Berah—Iphionia, Varthamia, Stachys, and Teucrium, were very conspicuous. Gomphocarpus often arrested attention, shedding its beautifully silky tufts of hair ready to whisk the attached seeds about the peninsula with every breath that blew. Phagnalon nitidum, Moq., Anabasis setifera, Moq., and Atriplex leucoclada, Boiss., occurred in Wady Solaf, so that the Salsolaceæ only require saline soil to appear in the upper country. In Wady Solaf, a smaller arm of the Wady es Sheikh, remarkable sections of marl deposits many feet in thickness were observed. These, no doubt, represent considerable lacustrine deposits of no remote geological period, since cut through by streams of considerable volume and supply.

At Jebel Watayeh a fine granitic pass connects the eastern and southern prolongations of Wady es Sheikh. The summit of the peak I estimated at 4150 feet above sea level. On it I obtained Dianthus sinaicus, Boiss.; Buffonia multiceps, D. C.; Arenaria graveolens, Sch.; Cratægus sinaica, Boiss.; Cotyledon umbilicus, Linn. (?); Poa sinaica, St. (?), and most of the species of Zibb el Baheir. The withered Psoralea, sp. (?), also occurred again. The first two of these are peculiar to Sinai. There was a well-marked difference between the plants of the north and south sides of this peak; the Cotyledon and the Poa, representatives of more temperate countries, occurred only on the northern shady side, while Artemisiæ, Anabasis, Zilla, and other ubiquitous desert plants prevailed on the sunnier southern face.

Further on towards Wady Zuweirah were collected Pyrethrum santalinoides, D. C.; Centaurea eryngoides, Linn.; Alkanna orientalis, Boiss.;

Lithospermum tenuiflorum, Linn.; Suæda monoica, Forsk.; Piptatherum multiflorum, Beauv., and of rarer sorts, Echinops glaberrimus, D. C.; Iphiona juniperifolia, Cass.; S. montana, Vahl.; Anarrhinum pubescens, Fres.; Primula boveana, Dcne., and Teucrium sinaicum, Boiss. The Alkanna is a clammy plant, with very showy orange flowers in full bloom. The Centaurea is a fine species, with strongly spined involucres and dense wool about the base of the stem. It was very far gone, and it was with difficulty I got enough to prove its identity. The Echinops (a peculiarly Sinaitic species, as was supposed, but found by me on Mount Hor) is a pretty blue-headed Centaurea-like plant.

It was interesting to notice a form of our Cotyledon umbilicus, Linn., the only apparently native British Dicotyledon I met with in Sinai. The Tamarisk is, perhaps, not native in England, and the Mallow, above mentioned, probably introduced in Sinai. This Cotyledon had been gathered here previously by Bovè, according to Decaisne, who mentions it under the present name. Mons. Boissier does not appear to have received specimens; and, unfortunately, mine are in too bad a condition to determine with certainty, consisting only of young leaves and a withered flowering stem. The root is tuberous. It was found plentifully afterwards on Mount Hor, and is not unlikely to be identical with the new form of Dr. Schweinfurth, gathered on the mountains between the Red Sea and the Nile Valley.

Retama retam, Forsk., is very common in these high level wadies. It quite takes the place of Acacia, and was now covered with its one-seeded capsules. The showy-bracted variety of Anabasis articulata was common also; this species is quite abnormal at this season, having dropped its more slender twigs, and looking much more like a Zygophyllum (*e. g.* Z. dumosum). It was not till I reached the Wady Araba that I saw it in its natural form.

We camped at Ain Zuweirah for the ascent of Mount Sinai. There is here a poor little garden, containing pomegranates, palms, and nubk (Zizyphus), apricots and mallow; and also, if I recollect aright, some olives. Gomphocarpus is abundant about this well. It is one of the most remarkable-looking species in Sinai.

I made the ascent of Jebel Musa and Jebel Catharine from this well on the 20th November. On the way to the Convent of Mount Sinai, which part was done on camel back, occurred Centaurea scoparia, Sieb.; Celsia parviflora, Dcne., and Alkanna orientalis, Boiss.; the latter abundantly. In the convent gardens were cypresses, oranges, figs, olives, date-palms, and vines in cultivation. These I saw hurriedly over the garden wall, for the delay in the convent was irksome, since the whole thing had to be done in a day. The convent stands at the base of the steepest part of the Mount Sinai ascent, at 5024 feet above sea level, according to the Ordnance Survey.

Near the convent on the way up the mountain were found Asperula sinaica, Dcne.; Pulicaria crispa, Forsk.; Verbascum sinaiticum, Bth.; Plantago arabica, Boiss.; Phlomis aurea, Dcne.; Nepeta septemcrenata, Ehr.; Mentha lavandulacea, Boiss.; Origanum maru, Linn., β. sinaicum; Ficus pseudosycomorus, Dcne., and Adiantum capillus-veneris, Linn. A solitary tree stands near the spring, but unfortunately I brought away no specimen of it. It was, I believe, Salix safsaf, Forsk.

At this height, about 5500 feet, across the valley a couple of palms, Phœnix dactylifera, Linn., occurred, and a tall cypress, Cupressus sempervirens, Linn., var. pyramidalis. The latter, which is not native (nor is the palm at this altitude), occurred again a little higher, in a conspicuous little plain, familiar to all travellers who have made the ascent.

Cotyledon umbilicus, Linn. (?); Arenaria graveolens, Schreb.; Scirpus holoschænus, Linn.; Peganum harmala, Linn.; Echinops and Acanthodium were gathered on the ascent. Several mosses were also secured.

On such excursions as these the Bedouins grew much excited as I eluded their guardianship, and rushed into gullies or up cliffs after some coveted treasure of vegetation not seen before. With howls and gestures they besought of me to return to the track. They are, indeed, held to a certain extent responsible for the safety of the travellers in their charge. It was this reason which caused such screams of dismay amongst the Pyramid Arabs as I succeeded in dodging them, and ascending the second and dangerous pyramid without their troublesome escort, and, what was to, them quite inexcusably unsafe, in my boots.

In spite then of the Bedouins I followed the bent of my own botanical

inclinations, and soon found out that they ceased to meddle when they saw they could not control. The mosses were the result of a detour from the path to a less open gully looking north. On or close to the summit, 7320 feet, were Cratægus sinaica, Boiss.; Artemisia herba-alba, Asso.; Verbascum sinaiticum, Bth.; Ruta tuberculata, Forsk.; Peganum harmala, Linn.; Arenaria graveolens, Sch.; Buffonia multiceps, Dcne.; Poa, sp.(?); P. sinaica (?), and Ephedra alte, C. A. M. The last is a curious twiggy undershrub, very brittle and almost leafless, belonging to the Gnetaceæ, and bearing more the character of an Equisetum than any other common species. The Mullein (Verbascum) is a remarkably thick-leaved velvety sort. It and the several labiates and scrophulariaceous plants were the most characteristic features in the botany of Mt. Sinai. Phlomis, Nepeta, Origanum, Teucrium, and Mentha were equal in quantity to all the other vegetation put together, and their pleasant savoury smells filled the air; Mt. Sinai may be called a mountain of labiates. The composites so common at about the mid altitudes were much scarcer here. The fern and the mosses best illustrate the coolness and the dampness of this elevated region, for the upper portion of Jebel Musa is supplied with a perennial spring.

Having left the party on the summit of Jebel Musa, I descended rapidly to the Convent of Deir el Arbain, about 1700 feet below, in the bottom of the gorge which separates Jebel Musa from Jebel Catharine. With a nimble Arab as guide, we rattled down this stony descent in half an hour. At the convent I was transferred to another native. There was barely daylight left in which to accomplish Jebel Catharine. From the summit of Jebel Musa it had looked magnificent, but evidently of far greater height. I had arranged that my camel should be in readiness here to bring me back to camp at Ain Zuweiriyeh at night. A quarter of an hour after my arrival at Deir el Arbain the faithful Khalîl appeared, and I started at half-past one p.m. for the summit.

At the monastery, or near it, were Bupleurum linearifolium, D.C., γ Schimperianum, J. & S.; Carum, sp. (?); Pterocephalus sanctus, Dcne.; Veronica syriaca, J. & S., a garden weed, and Celsia and Anarrhinum, already mentioned. These are chiefly endemic. Salix safsaf, Forsk., occurred here also.

During the ascent of the second mountain several of the Jebel Musa labiates were met with again, as Nepeta, Phlomis, and Stachys; but this mountain wore a far thinner vegetable coating than its neighbour. A lack of running water renders it more barren. At the small spring, Mayan esh Shunnâr (fountain of the partridge), I made another little collection of mosses, in all from the two mountains ten species, *i.e.* Grimmia apocarpa, Linn.; G. leucophæa, Grev.; Gymnostomum rupestre, Schwæg.; G. verticillatum; Tortula inermis, Mart.; Encalypta vulgaris, Hedw.; Entosthodon templetoni, Schwæg.; Bryum turbinatum, Hedw.; Hypnum veluinum, Linn.; and H. ruscifolium, Neck.* These are all British species with the exception of Tortula inermis, which occurs on the Morocco mountains, at 8000 to 10,000 feet, and I suppose elsewhere round the Mediterranean. One only in the list, Gymnostomum rupestre, is alpine in Great Britain. Several of these mosses are here first recorded from Sinai. Decaisne mentions four, two of which, not found by me, are common British species. This community of Musci so far apart is most unexpected.

The remainder of the ascent was over barren, perfectly unvegetated rock. Nevertheless, within a few hundred feet of the summit there was an exception, and I was delighted to find an exquisite little Colchicum, C. steveni, Kunth., in flower. It had no leaves, and bore either one, two, or three flowers on the scape—usually only one. It occurred again on the extreme summit, where it appears to have escaped previous notice, owing, no doubt, to the early season of flowering. C. steveni was afterwards gathered on Mount Hor, where the flowers were very decidedly smaller. The Jebel Catharine plant may prove to be distinct; its leaves are not synanthous, as they should be, according to Boissier. Oliver, however, refers it to the present name. This Colchicum has been recorded from the Palestine coast, but not farther south than Joppa.

On the summit there were barely traces of vegetation. I obtained Buffonia multiceps, Dcne.; Arenaria graveolens, Sch.; Herniaria sp. (?), (H. hemistemon ?); Gypsophila hirsuta, Led., δ. alpina, Boiss.; and fragments of an Astragalus, perhaps A. echinus, D. C. On the ascent I found roots and leaves of a sedge, looking like C. distans, Linn.

* These were determined by Mr. Mitten, F.L.S.

The temperature at the summit of Jebel Catharine was barely above freezing point. This is the highest point in the peninsula, 8536 feet above sea level. Judging from altitude and latitude, its mean annual temperature would about correspond with that of Edinburgh, but the drier atmosphere is no doubt unfavourable to vegetation. Absence of soil, except in sparse quantities, must also be considered.

The summit is a solid hump of syenite, with a lower shoulder joining it to a similar prominence about half a mile away. The view from here was magnificent, including the whole coast line of Sinai from Suez to Akaba, except the portion intercepted by the Um Shaumer range to the south, whose summit approaches in height that of Jebel Catharine within a few feet. Jebel Musa looked a mere trifle, one of a fierce sea of red-pointed and serrated ridges. To the east, across the Gulf of Akaba, the lofty Midianitish mountains appeared to reach about my own height, and to be of a similar construction. Northwards I was able to look over the escarpment and out on the "Desert of the Wanderings."

The summit was reached at a quarter past three, left at four, and the Convent of Deir el Arbain regained at five. A long camel ride by moonlight through a wild rocky gorge brought a memorable day to a close.

IV.—Mount Sinai to Akaba.

Our journeyings from Mount Sinai lay east of north to Akaba, skirting and occasionally crossing corners of the Tih plateau. This plateau of the Tih extends in a semicircular fashion far into the Sinaitic peninsula, with a steadily increasing elevation, until it terminates in the magnificent contour of cliffs known as the Tih escarpment. These, which are of white limestone, usually form everywhere a prominent feature northwards to the traveller in Sinai. It is only on ascending the greater elevations, as Jebel Musa and Jebel Catharine, that one feels at last the comfortable satisfaction of looking over and across the escarpment.

Our course lay along the Wady Zelegah, a noble valley-plain, about half a mile in width for upwards of twenty miles. It is bounded by precipitous sandstone cliffs, usually surmounted by cretaceous limestone.

Several detours were made by me into the Tih cliffs on the left of the line of our march. The chief plants met with were species of Glaucium, Capparis, Cleome, Ruta, Odontospermum, Artemisia, Sonchus and Verbascum, already mentioned. Artemisia herba-alba, Asso, is especially abundant and variable. Moricandia dumosa, Boiss., a glaucous-leaved, purple-flowered crucifer, was here first obtained. Capparis spinosa, Linn., var. Ægyptiaca; Iphiona scabra, Del., and Imperata cylindrica, Beauv., were also first met with. The furze-like composite Iphiona became frequent. The handsome reed Imperata occurred sparingly.

On the whole, the flora had hardly changed. Tamarix, Caylusea, Retama, Ochradenus, Zilla, Santolina, Ballota, Stachys, Lavandula, Anabasis, of species already mentioned, make up the list. Several Mount Sinai labiates were for the present missing, as also were two or three of the Iphiona group of composites. The larger Capparis was very frequent, growing on the most arid rocks above the Wady beds, where nothing else, except perhaps Lavandula coronopifolia, Poir., appeared able to exist. This Capparis (C. galeata), is sometimes an erect shrub six or eight feet high, of a bright green, differing much in appearance from the more slender trailing blue-foliaged species C. spinosa, var. Ægyptica, which often grows with it. The former was now in fruit; the latter barren. Camels delight in the larger grasses, in Ochradenus, Zilla, Nitraria, Anabasis, and Tamarisks.

At the head of Wady Elain, a grove of tamarisks was plentifully imbued with an exudation of greyish-white pillules of a viscid substance, with a taste of nucatine. This is the so-called "manna of Sinai," which is also obtained from Alhagi maurorum, D. C. This gum is said to be due to the puncture of a small insect. Several hours' gathering in this grove would have exhausted it and yielded perhaps a small cup full. It has to be gathered before the hot sun dries it up.

Here I first gathered a rare toad-flax, Linaria macilenta, Dcne. This spiny species was in flower; but so fugaceous was the corolla, that it was difficult to preserve a specimen. Cleome droserifolia, Del., with red-haired, sticky leaves, also occurred here. A spring supported a stream that moistened the soil for about a mile ere the combined effects of infiltration and evaporation caused it to disappear. Following its course, we were led

into an unexpected and magnificent fissure in the red granite, the Wady Elain, seldom visited by travellers. For five or six miles this gorge passes between sheer cliffs of richly-coloured rock, with a height varying from 500 to 800 feet, and from 10 to 50 yards wide. It is, in some ways, the most impressive feature in Sinai. The floor is hard, with an even slope northwards; and as the sun rarely hits the base of this cleft, many plants were here in a fresher condition than elsewhere, and some rarities were found. I will enumerate some of the most interesting species observed:—Moricandia sinaica, Boiss.; M. dumosa, Boiss.; Cleome droserifolia, Del.; Abutilon fruticosum, G. & P.; Zygophyllum coccineum, Linn.; Tephrosia purpurea, Pers.; Francœuria crispa, Boiss.; Blumea (Erigeron) bovei, D. C.; Iphiona scabra, Del.; Sonchus (Microrhynchus) nudicaule, Linn.; Scrophularia deserti, Del.; Linaria macilenta, Dcne.; Lycium arabicum, Sch.; Hyoscyamus aureus, Linn.; H. muticus, Linn.; Ballota schimperiana, Bth.; Teucrium sinaicum, Boiss.; Origanum sinaicum, Boiss.; Atriplex leucoclada, Boiss.; Typha angustata, B. C.; Cyperus lævigatus, Linn., et var junciformis; Panicum turgidum, Forsk.; Pennisetum dichotomum, Del.; Imperata cylindrica, Beauv., and forms of Reseda pruinosa, Del.; Fagonia cretica, Linn.; as well as other indeterminable fragments. Several of the above are peculiar to Sinai; and some mentioned here and elsewhere are now first included in its flora.

It was with some misgivings we camped in this wady. Had a "seil" visited us, like the Rev. F. Holland's memorable one at Wady Feiran, we should have had a bad time.* But the expected rain did not arrive.

While encamped here for Sunday we received notice of an unusual and exciting event, the arrival of visitors from England, for whom our courteous chief at once had coffee prepared. The party, however, consisting of engineers, Colonel Colville, and others, passed us at speed on the opposite side of the narrow valley without deigning to notice us. Suspecting that this impetuous haste and lack of that courtesy, for which Englishmen on their travels are so justly famous, arose from ulterior motives, Professor Hull convened a council, which resulted in despatching our able conductor, Bernard Heilpern, with orders to secure our entitled priority to the Akaba

* See "Ordinance Survey of Sinai" for an account of this "seil" or torrent.

sheikh's services and camels. Bernard passed the fugitives in the night, and was entirely successful.

It was long ere we got clear of the ever-widening, slowly-rising Wady El Tihyeh, which wound through rounded granite hills, and lifted us out of the Wady Elain. Our height above sea-level varied between 2500 and 3000 feet, as estimated by my aneroid. Acacias were numerous, chiefly A. seyal. These granite hills were frequently capped with a stratum of sandstone, and were barren to an excessive degree. The two species of Capparis, Dæmia cordata and Tephrosia purpurea, are the only noteworthy plants. The Arabs eat the ripe red fruit of the larger caper. I tasted it, but did not care to pursue the inquiry. The skin is mustard, and the seed black pepper.

In marshy places, at the head of Wady Elain, amongst palms and tamarisks, Typha angustata was twelve to fourteen feet high; Erigeron bovei six or seven feet high, well branched, and with numerous flower-heads; and Phragmites gigantea was fully fifteen feet in height.

The pricklier plants, Acacias, Acanthodium, Gymnocarpum, &c., are perhaps generally commoner in proportion to the others on the granite and sandstone than on limestone.

In a very dirty well (Bir Es Sowrah), near the base of Jebel Aradah, I found Chara hispida, Linn., an ubiquitous aquatic, and with it the Arabian variety of our own common sea rush. Lavandula coronopifolia, Poir., must be credited with almost unequalled powers of sustaining life in these barren rocks.

We were now crossing a little-known and unsurveyed region. Consequently there was abundant work for the engineering section of our party. Ruppell, Laborde, Weiss, Martineau, and Holland are amongst the few who have traversed this country, and I was sorely disappointed to find that on the table-land we were now entering there was little living vegetation, although abundant evidence of a sparse but varied flora.

The table-land, called here Jebel Hirtih, is, properly speaking, a portion of the Tih plateau, which becomes indefinitely bounded at its south-eastern border. Here, as on Jebel Aradah, there was little recognizable

plant life; Gymnocarpum, Reaumuria, Capparis, Acanthodium (Blepharis) edulis, and Lavandula may be mentioned.

A fine oval plain, Wady Hessih, now clad with withered scraps, is here a favourite pasturing place for the Bedouins' flocks. Here I collected Tribulus alatus, D. C.; Anastatica hierochuntinah, Linn.; Zygophyllum dumosum, Boiss.; Lotus lanuginosus, Linn.; Ifloga spicata, Forsk.; Filago prostrata, Parlat.; Linaria floribunda, Boiss.; Verbascum sinuatum, Linn.; Heliotropium undulatum, Vahl.; Micromeria myrifolia, Boiss.; Plantago ovata, Forsk.; Panicum teneriffæ, R. Br., and Aristida cœrulescens, Desf. These had not been previously met with. The Anastatica, the well-known "Rose of Jericho," is common. The claims of Anastatica to being this plant of the mediæval travellers have been of late disputed, those of Asteriscus pygmæus being advanced by a recent French writer.

Farsetia, Reseda pruinosa, Polycarpœa, Helianthemum, Atractylis flava, and Zygophyllum album also occur, as well as commoner sorts.

In this depression, where water and soil are of more frequent occurrence, there is an abundance of greyish scrub, short, thin, and interrupted, and composed chiefly of Anabasis, Ephedra, Atriplices, Nitraria, Zilla, and Retama. Lindenbergia, Dæmia, and Gomphocarpus still occur with Sonchus nudicaulis. The Anabasis always goes by the name of "Rinth" with the Arabs. Camels eat even the milky Asclepiads, although Dæmia is said to be poisonous. As we approached the Hadj caravan route, from Suez to Akaba, I first met with Heliotropium arbainense, Fres. Those two especially nauseous plants, Pegamum and Ruta, were very common. The former smells like our hound's tongue, the latter like a species of harvest-bug. Cleome droserifolia smells like a fox. We were here on limestone, the Acacia being almost or entirely absent.

These latter remarks apply to the dreary monotonous waste between Wady Elain and the Hadj road, the northern border of the peninsula.

On the 29th November we descended by a magnificent gorge between walls of granite and limestone, by the Hadj road to Akaba. The ever-varying peeps of the gorgeously-blue gulf, shining in an intense sunlight, were most refreshing after the hopeless desolation of the desert. The

rich purple colouring of the opposite lofty mountains of Midian formed a noble background.

V.—AKABA TO MOUNT HOR.

At Akaba we remained from November 29 to December 8. I increased my collections here considerably. The flora displayed several fresh species. Hyphæne thebaica, Del., the doum palm, reaches here its northern limit; it has been observed here by Mr. Redhead. Captain Burton found it abundant on the east coasts of the Red Sea, a little further south.

In the enclosures at the straggling Arab village, with an Egyptian fortress, I noticed nubk (Zizyphus), henna (Lawsonia), palms, tamarinds, Cassia fistula (?), figs, and several melons. Most esculents were in a seedling state.

The following plants were identified as occurring at Akaba:—Cassia acutifolia, D. C.; C. obovata, Coll.; Onobrychis ptolemaica, Del.; Tephrosea apollinea, Del.; Artemisia monosperma, Del.; Statice pruinosa, Linn.; Salvia deserti, Dcne.; Boerhaavia plumbaginea, Cav.; Calligonum comosum, L'Her.; Atriplex crystallina, Ehr., and Andropogon foveolatus, Del. A few other less common species already found may be indicated by their genera: Lotononis, Tephrosia, Sonchus, Cucumis, Linaria, Trichodesma, Forskahlea, Andrachne, Heliotropium arbainense, and Polycarpæa. Along the shore in some places was a close growth of Nitraria, Atriplices (A. halimus, A. leucocladum, A. crystallinum), Juncus, and others. Cressa cretica is a characteristic species along the shore in the saline soil.

At Akaba we were at the head of the Gulf, and the southern extremity of the Wady Araba. We had left the Sinaitic peninsula. From here we turned northwards up the Araba, and happily for me we had occasion to travel more slowly to suit the requirements of the surveying party. I was then enabled to make wide detours east and west out of the Araba, but my inclination lay chiefly eastwards, to the wadies and mountains abutting on the high table-land of Edom.

This wady was full of animal life; in addition to the multitudes of various rodents, gazelles were also frequently seen. I met with ibexes,

and a hyæna, and fresh tracks and other signs of the leopard were seen in several places.

From El Taba, about twenty-five miles north from Akaba, a grove of acacias extends almost uninterruptedly along the eastern edge of the wide valley of the Araba for about ten miles. The trees are scattered, chiefly A. tortilis, Hayne, and some 'Seyal' and Zizyphus. On these trees the handsome parasite Loranthus acaciæ, Zucc., a plant of the mistletoe order, with showy red flowers, was conspicuous. Here I also found Cocculus lecœba, D. C.; Salsola fœtida, Forsk.; and Eragrostis cynosurides, Retz.; the latter red-flowered grass was plentiful about the marsh of El Taba. In opener ground the vegetation was composed of those desert species mentioned at Akaba, with our old friends Citrullus, Monsonia, Glaucium, Pancratium, Cucumis, and Danthonia. In some places the Araba is spanned by rolling wastes of sand dunes, ten to twelve feet high, accumulated round, and often smothering, clumps of tamarisk and anabasis. Near to Akaba there is a depression in the centre of the valley, an old lake basin of salt mud, which I crossed and re-crossed, and examined with care. It was utterly barren both of existing and sub-fossil organisms.

On the 7th December a long day's climbing with my friend Laurence brought us to the head of Wady Ghurundel, in Edom, at a height of about 1800 feet above sea level, six miles east from the Araba. The scenery during this climb was superb. Mural blocks of red sandstone, 800 to 1000 feet high, towered in detached masses above us, giving in some places abundant evidence of the fearful rate at which disintegration proceeds in rock which is entirely exposed to violent atmospheric effects. We passed a spring with a few date palms, and a little higher a large broad-leaved bulb appeared, and soon became abundant. It was, I believe, an Urginea, but was not found in blow. Dianthus multipunctatus, Leb.; Eryngium, (?) sp., Asteriscus pygmæus, Coss.; Cotula cinerea, Del.; Solanum nigrum, Linn., var. moschatum; Satureia cuneifolia, Ten., forma; Boerhaavia verticillata, Desf.; Ficus sycamorus, Linn.; Traganum nudatum, Del.; Aristida ciliata, Desf., first appeared here. The Asteriscus was a little woody button, representing the hardened flower-head, usually solitary and close to the ground. This is M. Michon's "Rose of Jericho," but the prior and

stronger claims of Anastatica will not be readily foregone. The Boerhaavias, of which I have now mentioned two species, are pretty entire or ivy-leaved decumbent or climbing species, with panicles of pinkish small flowers, and characteristic of hot regions. The Satureia, or savory, was a deliciously fragrant labiate, not in flower. Other species of interest were:—Morican-dia dumosa, Boiss.; Abutilon fruticosum, G. & P.; Iphiona scabra, Del.; I. juniperifolia, Cass.; Varthamia montana, Vahl.; Centaurea scoparia, Sieb.; and Ballota undulata, Fres.

Judging from the abundance of its bur-like carpels lying in the dry water-course, Calligonum comosum, now in a withered condition, is an abundant species. One or two bulbous species, as yet undetermined, occurred here. A stiff scramble brought us back to the Araba by a more northern valley. The Calligonum is a dry, grey, leafless, jointed shrub, now completely fallen to pieces, except in rare instances.

This last valley had shown us some characteristic Sinaitic species, extending their range across the Araba north-eastwards to Edom. Several more will presently be mentioned, and all will be spoken of together. A suggestion may here be hazarded, that it is probably from our ignorance of the Arabian flora that many of these Sinaitic plants are unknown elsewhere. A large proportion of the Sinaitic flora is of eastern origin.

Owing to the greater moisture found in the upper parts of some of the wadies of the Edomitic escarpment, there is a greater variety of species, and a sprinkling of ferns, mosses, and lichens. These are often more northern forms, which have spread southwards at high levels.

We then entered a district which Canon Tristram has somewhat liberally included in Palestine. As it had not previously been botanized, it adds several to that gentleman's list of Palestine plants. I will speak first of the wadies, and then of Mount Hor and Petra.

The following plants, not previously met with, were gathered in Wady Abou Kosheibeh (W. Haroun), and on the peaked mountain which stands in a commanding position at its head:—Fumaria micrantha, Lag.; Erodium hirtum, Forsk.; Poterium verrucosum (?), Ehr.; Anvillea garcini, D. C.; Carthamus glauca, M. B.; C. lanatus, Linn.; Globularia arabica, J. & S.; Podonosma syriaca, Lab.; Nerium oleander, Linn.; Pentatropis spiralis,

Forsk.; Boucerosia, sp. nov.; Salvia ægyptiaca, Linn.; Juniperus phœnicea, Linn.; Bellevallia flexuosa, Boiss.; Asparagus aphyllus, Linn.; Asphodelus ramosus, Linn.; Pennisetum cenchroides, Rich.; Cheilanthes odora, Sw., and Notholæna lanuginosa, Desf. Of these, Globularia, Podonosma, Boucerosia, Juniperus, and the two ferns, were amongst the cliffs above the wady at about 3000 feet above sea level. The Globularia, an Eastern form of G. alyssum, is a pretty compact little shrub, with hard entire small leaves, and blue heads of florets. The asclepiads Boucerosia and Pentatropis were frequent. The latter is probably P. spiralis, but as it was not in flower Mr. Oliver would not speak with certainty. It occurred again climbing over acacias. The Boucerosia may be B. aucheriana, Dcne., an insufficiently described plant from Mascat, in S. E. Arabia, which is also the nearest known habitat for the Pentatropis. The Oleander is abundant, but was not in flower. Juniper grows to a good size: at the summit of Jebel Abou Kosheibeh, a tree about twenty feet high had a trunk at least a foot thick. I could see junipers on all the surrounding heights.

On this mountain I gathered also Moricandia, Gomphocarpus, Helianthemum, Cotyledon, Linaria macilenta, Verbascum sinaiticum, Phlomis, and Boerhaavia verticillatum, species lately mentioned.

Reaumuria, Ochradenus, Zygophyllum, Morettia, Zilla, Acacia, Retama, Ruta, Ifloga, Lycium, Trichodesma, Forskahlea, Asphodelus, Anabasis, Ephedra, and grasses already mentioned, occurred in the wady.

It will thus be seen that the flora of Sinai is, in fact, that of Edom, and that the Wady Araba causes no alteration of consequence. A slight increase of species from north and east is observed.

The Wady Haroun is at first wide and arid, but after a few miles vegetation rapidly increases. The flanks of the Edomitic limestone escarpment are better supplied with water than the Sinaitic granite. Banks of loam by the edge of this valley at a moderate elevation, 1000 to 1500 feet above the sea, had a sprinkling of mosses and other cryptogams. The mosses were chiefly of the genus Tortula, of which five species were collected. Side by side with these grew the desert plants in great abundance. Dæmia, for instance, climbed to a height of ten or twelve feet in retam bushes, the

support being as well developed as the climbing plant. In the open desert, Dæmia, as noticed by Mr. Redhead, lies sprawling on the ground, its several stems sometimes closely twisted into a thong towards their extremities, so that circulation is paralyzed, and the young shoots are strangled. Changed conditions in the treeless waste have deprived this plant of its normal support, and even when this occurs it seems there to have lost its power of utilizing it, for I have seen Dæmia choking itself in Sinai side by side with bushes of the very sort which here supported it. The desert plant was more plentifully milky, and in other respects slightly different. We have here agencies at work which are no doubt producing a form more in harmony with its environment.

On the 10th of December we made the ascent of Mount Hor, returning to camp the same day by Petra. Our camp was fixed near the mouth of Wady Haroun. Although having made an early start (4 A.M.), our visit was a very hurried one. I had time, however, while the theodolite party were waiting for a cloud to lift, to make a good gathering of the bulbous plants now just showing about the summit.

The view from Mount Hor, whose height I estimated at 4400 feet, is disappointing, and bears no sort of comparison with those from the Sinai peaks. The day was not propitious, but the main defect was due to the adjoining monotonous table-land of Edom, which obscures one side of the horizon. This table-land averages perhaps 5000 feet in height, some ten miles or less east of Mount Hor, and is composed of the unvarying and unpicturesque cretaceous limestone. It lowers northwards, and I afterwards set foot on its outer flanks. In some places it appeared to have quite a forest vegetation.

As Mount Sinai is a mountain of labiates, so Mount Hor may be designated a mountain of bulbs. Mount Hor is very rich in plants, and many of the Jebel Musa labiates and composites occurred here, but in Monocotyledons there was the greatest increase. Only one bulbous species was found on Mount Sinai. On Mount Hor upwards of twenty occurred. Several of those which I brought home, I regret to say, cannot be determined. They are growing and showing leaves, but do not appear inclined to flower.

In the upper 1000 feet of Mount Hor (3500 feet to the summit) a

considerable accession of Mediterranean or more northern forms was first met with. These were—

Dianthus multipunctatus, Ser.	Colchicum montanum, Linn.
Geranium tuberosum, Linn.	C. steveni, Kunth. [also on Sinai].
Pistacia palæstina, Boiss.	? Urginea scilla, Sternh.
Rhamnus punctata, Boiss. var.	Bellevallia flexuosa, Boiss.
Paronychia argentea, Lam.	Asphodelus fistulosus, Linn.
Galium canum, Req.	Asparagus aphyllus, Linn.
Scrophularia heterophylla, Will.	A. acutifolius, Linn.
Bryonia syriaca, Boiss.	Arum, ? sp.
Sternbergia macrantha, Guy.	Carex stenophylla, Vahl.

A few of these were met with lower down in the neighbouring valleys, and some began to be common in all directions. A more important list is that of a few species believed to be peculiar to Sinai, but found now on Mount Hor and the adjacent peaks and valleys. These are—

Moricandia dumosa, Boiss.	? Micromeria sinaica, Bth.
Pterocephalus sanctus, Dcne.	Origanum sinaicum, Boiss.
Echinops glaberrimus, D. C.	Phlomis aurea, Dcne.
Varthamia montana, Vahl.	Teucrium sinaicum Bth.
Celsia parviflora, Dcne.	Allium sinaiticum, Boiss.

Both these lists would no doubt be swelled by other additions if any fortunate botanist obtained a leisurely visit at the proper season. Mount Hor should, however, be visited in January, and also in May, to secure both bulbs and later flowering species.

The arborescent vegetation of Mount Hor is confined to the summit or nearly so. It consisted of a bladder senna, Colutea aleppica, Lam., a turpentine tree, Pistacia palestina, Boiss., and the juniper already mentioned, J. phœnicea. Each of these was about ten or twelve feet high. The Rhamnus, already mentioned, was very much stunted.

At Petra, two new species were discovered, which will be described further on. One was a Galium, allied to G. jungermannioides, Boiss., a low, straggling species, somewhat matted, with the habit of our Asperula cynanchica, Linn. It occurred in rocky clefts in the "Sîk" at Petra.

The other new species was a Daphne, an erect shrub six or seven feet high, with long linear leaves, reddish-brown berries, and small cream-coloured flowers. The fibre is remarkably stringy. This Daphne is allied to D. acuminata and D. mucronata, but differs materially from both these species. It was found in flower and fruit. The Galium, though in fruit, was without fresh petals. M. Boissier has pronounced it new. The Daphne occurred on the slopes of Mount Hor, about a mile from Petra, and again, at intervals, lower down. Boucerosia, already mentioned, was found on Mount Hor in several places. (Plates XVI. and XVII.)

Unrecognizable fragments of Umbelliferæ, Scrophulariaceæ, Gramineæ, and others, occurred at Petra. A good harvest awaits the botanist who arrives here in due season and with sufficient leisure. My time in Petra was somewhat less than an hour.

The following plants from Petra and Mount Hor were there first seen. These must be added to the list already given, and those of Abou Kosheibeh, all of which, I think, occurred on Mount Hor. Diplotaxis pendula, D. C.; Ononis vaginalis, Vahl.; Rubia peregrina, Linn.; Inula viscosa, Desf.; Zollikoferia cassiniana, Jaub.; Thymelæa hirsuta, Linn.; Salsola rigida, Pall.; S. inermis, Forsk.; Noea spinosissima, Moq.; Polygonum equisetiforme, J. & S.; Asplenium ceterach, Linn., and Andropogon hirtus, Linn.

On the subject of zonal altitudes, I extract a few notes from my journal. At 3000 feet and upwards, oleander and tamarisks ceased; scilla abundant. At 3450 feet, Thymelæa (Passerina) hirsuta first occured; at 3500 feet, numerous species occured, as Pterocephalus, Globularia, Onosma, Juniper, Ceterach, Cheilanthes, Fagonia, Cotyledon, Capparis, Varthamia, Phlomis, Ononis, Deverra, Moricandia dumosa, Rhamnus, to 3750 feet and upwards; at or near the summit (4400 feet, *circa*) were Geranium, Colutea, Pistacia, Rhamnus, Pennisetum cenchroides, Hyoscyamus aureus, Noea, Poterium spinosum, Scilla, Malva, Carex, Ephedra, Zollikoferia, Echinops, Sternbergia, Verbascum sinuatum, Origanum, Ajuga tridactylites, Arum (? sp.), Bryonia, and Colchicum. These observations were taken on the ascent from the south-west. Petra stands at about 3000 feet on the northern side, and many of these were somewhat lower there. Phlomis, Ononis, Thymelæa, Rubia, Rhamnus, Pistacia, Inula, Sternbergia, Bellevallia, Rumex

roseus, Verbascum sinaiticum, Ficus sycamorus, all occurred at Petra. The Ononis, very viscid, with pretty yellow and claret-coloured veined flowers, was, with Thymelæa, Colchicum, and Sternbergia, common and characteristic of the upper height, but descending a good deal lower (500 feet) on the north side. Sternbergia macrantha was glorious, with flowers of golden yellow as large as a lemon.

VI.—Petra to the Dead Sea.

The mouth of Wady Haroun into the Araba is somewhat more than half way from Akaba to the Dead Sea. The watershed between the Dead Sea and the Gulf of Akaba is a little nearer to Akaba, its lowest point being estimated at from 650 to 700 feet above sea level at the Red Sea. It lies slightly west of the main valley of the Araba, which is here at its widest, being about thirteen miles across. The total length of the valley from Akaba to the Dead Sea is 112 miles.

My chief detour in this part of the Araba was up a valley on the east side to the Edomitic escarpment, with Mr. Armstrong. On this occasion we returned to the Araba by a more northern valley, Wady Ghuweir, which, from numerous remains of encampments, tribe-marks, and well-worn tracks, appeared to be a leading thoroughfare into the Shobek country, and perhaps used as the pilgrimage route from Gaza to Mecca.

In Wady Ghuweir are several springs. These frequently appear at the union of the sandstone and limestone formations. One of these springs supported a jungle of reeds with palms and tall compositæ of luxuriant growth. Tamarisks, acacias, and nubk trees (Zizyphus) were in some profusion; and on each of these sorts of trees the handsome parasite, Loranthus acaciæ, was a conspicuous ornament. It occurred only two or three times on the tamarisk, oftener on the nubk, but most commonly on the acacia. Climbing over the reeds was another asclepiad, a European species, Cynanchum acutum, Linn., with inconspicuous, small white flowers, and something of the habit of our bindweed. Amongst the reeds was the stately Saccharum ægyptiacum, W.; and the shrubby composite, Pluchea dioscorides, D. C., reaches a height of fifteen feet. Its flowers

are insignificant. A red-barked osier, Salix acmophylla, Boiss., and a poplar, Populus euphratica, Linn., which is, perhaps, the willow of Babylon, occurred along the margin of the short-lived stream.

Other species collected were Erucaria aleppica, Linn.; Tribulus terrestris, Linn.; Ficus carica, Linn.; Salsola tetragona, Del.; and others less noteworthy. The fragrant Satureia cuneifolia and the sticky Sekkaran (Hyoscyamus muticus) were also noticed.

At the head of this valley, Juniperus phœnicea was found to be the tree visible from the Araba on the white, chalky plateau of Edom, growing abundantly. Burton found this tree luxuriant and common at considerable heights in Midian, three degrees further south.

Maiden-hair fern occurred in this wady. Lycium arabicum and Boerhaavia verticillata, tropical species, were also frequent. Bushes of "nubk" were sometimes "quite o'ercanopied" with this latter trailing species, with its pretty panicles of pinkish-blue flowers.

The Arabs say that with the juniper on Edom grows also "balut," Quercus coccifera, Linn., and "arour," a thorn, with a small, sweet fruit. This is, probably, Rhus oxyacanthoides, Linn., which I found at Jericho, and which the above-mentioned traveller (Burton) tells us is common in Midian.

In this part of the Araba, the beautiful Pancratium was frequently gathered. At Ain Abou Werideh, a little south of Wady Ghuweir, many old desert friends still occurred. The poplar was here of goodly size. No less than three running streams maintained a brief but productive existence across the sands. Prosopis stephaniana, Willd.; Statice pruinosa, Linn.; Artemisia monosperma, Del.; Sucœda asphaltica, Boiss.; Salsola fœtida, Forsk., and many others, were collected. The Prosopis is a little scrubby acacia confined to salt marls. Several species of bulbous plants were also obtained here.

Further north, towards the Ghor or Dead Sea depression, I collected Eremobium lineare, Del.; Monsonia nivea, Dcne.; Anastatica hierochuntina, Linn. ("Rose of Jericho"); Astragalus forskahlii, Boiss.; A. aciniciferus, Boiss.; Rhamnus, ? sp.; Carthamus glaucus, M.B.; Androcymbium (Erythrostictus) palæstina, Baker.; Allium sinaiticum, Boiss.; Aristida

ciliata, Desf.; A. plumosa, Linn.; Panicum turgidum, Forsk.; with the commoner desert species.

On the night of the 14th we were visited with a thunderstorm and a tremendous downpour of rain. Rain had fallen once since we left Cairo, on the 3rd December, the day we left Akaba.

On the 16th December we obtained our first view of the Dead Sea, and descended to the plain at its southern extremity. The whole depression in which the Dead Sea lies, 1300 feet below sea level at its surface, is called the Ghor or Hollow. On the first night we camped in the Ghor el Feifeh; and from the 17th to the 26th, inclusive, we were detained at the Ghor es Safieh while waiting for means of transport from Jerusalem.

This enforced delay in so remarkable a locality was to me a most fortunate occurrence. Previous visitors do not appear to have obtained more than a hurried view. The difficulties arise from the constant petty warfare in which the surrounding Arabs are engaged, the fertile Ghor being frequently the scene and object of their conflicts.

The Ghor es Safieh lies at the south-eastern end of the Dead Sea, about 1250 feet below the level of the Mediterranean. It is watered by the Garahi river, as the Ghor el Feifeh is by the Tufileh, both descending from the eastern highlands. Both these streams were well supplied with water during our visit; and the larger, which was that of the Safieh, is distributed into watercourses for irrigating purposes by the cultivating Arabs who live there. From this tribe, the Ghawarinheh, I never received the smallest annoyance during my constant solitary rambles about their territory.

No sooner has the Seil Garahi or Herssi issued from its unfruitful though remarkable defile in the eastern sandstone, than the whole scene changes as if by magic. The barren white marls, with which the neighbouring rocks are covered to a height of 650 feet above the Dead Sea level, disappear; and the whole lower plain of the Ghor is a scene of luxuriant fertility. Wheat, barley, oats, dhourra (Sorghum), indigo (one sort), tobacco, and indian corn, are cultivated in their proper seasons. An extensive growth of bushy, low-sized trees almost covers the district. In the Upper Ghor, these are usually tangled and matted, almost to the exclusion

of other growth. In the Ghor es Safieh the trees are more scattered; no doubt, consumed for firing, and thinned to admit of pasturage and crops.

These trees are chiefly acacias of three sorts, Salvadora, Balanites, Zizyphus, Rhamnus, Populus, and Moringa. Of these, the arak or Salvadora (S. persica, Gært.) is the most abundant, and usually occupies a slightly lower region than the acacia. It grows in clumps, several stems arising from one stock to form a single tree. It is very leafy, with leathery leaves of no great size, and numerous little flowers, and globular fruit less than white currants. It is about twenty feet high, and is one of the characteristic tropical species of the Ghor. The Balanites "zukkum," or "false balm of Gilead" (B. ægyptica, Del.), is usually a smaller tree, and was then bearing its wrinkled green fruit about the size of a walnut. The Zizyphus is the well-known "nubk" or sidr (thorn) of the Arabs—the "dôm" when reaching a large size. Its fruit, about the size of a Siberian crab, is in much request. Its spiny branches, strewed along the ground, form fences against cattle.

As the plain slowly lowers to the Dead Sea, becoming at the same time moister and salter, the forms of vegetation gradually change. The above species decrease in the number of individuals representing them. Tamarisks, Osher (Calotropis procera, Willd.), Salsolas, Prosopis, and Atriplices take their place in abundance. Of these, the tropical osher is the most remarkable. It might be compared to a gigantic cabbage, ten to fifteen feet high, but that the leaves are hardly large enough. It has also an infusion of cactus growth and the bark of a cork-tree, and is utterly strange-looking to European eyes. Its fruit, the size of an orange, is full of air and silk, and is probably to be identified with the apples of the Dead Sea. Castor oil (Ricinus communis) is also very conspicuous, and reaches a height of over twenty feet, chiefly in the same localities as the osher. Both grow near the Dead Sea, and also on the banks of the Garahi. Other bushes are the leafless Leptadenia pyrotechnica, osiers, and oleanders. The latter two are confined to the places where the stream issues from the mountain, or higher up.

Approaching the Dead Sea, occasional swamps, caused by the stag-

nating stream, produce jungles of various tall grasses, chiefly Arundo phragmitis (P. gigantea, J. Gay); Erianthus ravennæ, Beauv.; and Imperata cylindrica, P. de B.; mixed with several Cyperaceæ, of which the most interesting were C. eleusinoides, Kunth.; and, sparingly, C. papyrus, Linn. Salter patches, away from the access of the stream, are given up to Juncus maritimus, Linn., and Eragrostis cynosuroides, Retz.. The former (var. arabica) was from four to seven feet high. Tamarisks, Suædæ, Salsola, Salicornias and Atriplices were the last to fail. Tamarix nilotica ?, Salicornia herbacea, and a Ruppia not in flower, probably R. spiralis, L. Her., were the very last; the former along the border of the uppermost beach line; the latter two on lower ground, sometimes covered by the sea, where the mud of the Tufileh river meets the saline slob.

An interesting assemblage of plants, usually elsewhere maritime, is congregated around the Dead Sea. These are Sonchus maritimus, Linn.; Inula crithmoides, Linn.; Lotus tenuifolius, Rchb.; Salicornia herbacea, Linn.; several species of Salsola, Suæda, and Atriplex, Scirpus maritimus, Linn.; Fimbristylis dichotoma, Rottb.; Juncus maritimus, Linn.; and Ruppia (? sp.), R. spiralis, ? L. H. Some of these, at first sight, convey the idea that we have here an isolated detachment of the sea itself, with its flora remaining from some ancient time; but a little reflection will show that the proximity of both Mediterranean and Red Seas, together with direct intercourse of human beings and aquatic birds, will suffice to explain their presence, especially when we consider the suitable salinity of the soil and atmosphere.

Several of the most interesting plants were obtained by penetrating these jungles in all directions. The luxuriance in them of some familiar British plants may be alluded to. The rush reaches seven or eight feet in height. Inula crithmoides was four to seven feet high; Lycopus europæus, five to six feet high; while gigantic plants of Lythrum salicaria stood full fourteen feet from the ground.

One of the most interesting finds was that of a handsome acacia, A. læta, Br., in the Ghor. This species has not been recorded north of Assouan, seven degrees further south. Like many others of those mentioned,

it illustrates the almost tropical heat of the "sultry depression" of the Ghor. This acacia is larger and better furnished than the other species. There were several trees of it. The fruit is very distinct from A. seyal and A. tortilis.

A few other remarkable species, not noticed by previous botanists in Palestine, may be mentioned:—Cocculus leœba, D. C.; Sclerocephalus arabicus, Boiss.; Zygophyllum simplex, Linn.; Indigofera paucifolia, Del.; Rhynchosia minima, D. C.; Trianthema pentandra, Linn.; Eclipta alba, Linn.; Salsolaceæ (several); Pentatropis spiralis, R. Br.; Digera arvensis, Forsk.; Boerhaavia verticillata, Poir.; B. repens, Linn.; Euphorbia ægyptiaca, Boiss.; and Cyperus eleusinoides, Kunth. The majority of these are distinctly tropical, and add importantly to that most interesting group of those plants already known to inhabit the Ghor.

I gathered altogether, at the southern end of the Dead Sea, about 225 identifiable species of flowering plants. The total may reach 300. Many annuals and Mediterranean spring plants, especially of the Leguminose and Cruciferous orders, were still in too young a condition to name.

The Ghor has been visited by two competent botanists, Messrs. B. T. Lowne, in 1864, and W. Amherst Hayne, in 1872, both in connexion with Canon Tristram's indefatigable explorations. These gentlemen have, however, hardly dealt with the oasis of Es Safieh. Mr. Hayne's essay, appended to Canon Tristram's "Land of Moab," is only enough to make a botanist want more; while Mr. Lowne's valuable Paper in the Linnean Society Proceedings deals with the south-western extremity of the Ghor, whose flora is that of the desert, and forms the northern limit, slightly continued to Jericho, of that of Sinai and the Araba.

At the time of our visit the mean diurnal temperature was about 50° Fahr. There is no universal check to vegetation in the Ghor. Acacias, Osher, Castor-oil, Loranthus, Salvadora, species of Abutilon, Zizyphus, and Balanites were bearing fruit and flower in true tropical fashion at the time of our visit, which was within a very few days and degrees of the coldest season.

Before we left corn was just showing, a delicate hue of green being perceptible across the ill-tilled enclosures. A striking peculiarity of the flora may be finally mentioned. This is the number of species compared

with the number of individuals. If those few gregarious kinds, chiefly trees, shrubs, and grasses, already mentioned, be eliminated, the remaining sorts would often depend on a few plants for their place to a claim on the list. Hence brief visits may be expected to give rise to omissions.

VII. Ghor es Safieh to Gaza.

On the 27th of December we finally struck tents, and left our camp in the Ghor es Safieh. As we passed westwards, near the south end of the Dead Sea, the variations in its levels at different seasons were noticeable. This amounts to about three feet in depth at the greatest difference. During our visit the waters were low; and a line of drift of timber, floated shells, seeds, dead insects, and other *rejectamenta*, which met their death on being carried to its waters, showed an upper margin at a uniform height at several places. An older recent-looking margin was apparent at the base of Jebel Usdum, at the south-west end of the Dead Sea. This stood about seven feet above the present high-water drift, and points to a still-continuing reduction of the mean level of the lake. These margins are frequently marked by logs of the date-palm, usually sub-fossil, and torn out of the marls by floods.

Of Jebel Usdum, which had not previously been climbed, I have given a description to Professor Hull, which he has inserted in his volume about our expedition. It proved to be of some botanical interest, yielding a good variety of Salsolaceæ. It is about 650 feet high, and consists of a nucleus of rocksalt, capped by the marly deposit of the old sea-bed. The plants on its barren, chalky, dusty slopes were very few; and, on the flat summit, a couple of solitary tamarisks alone occured. On the western side a water-course, cut through the marls, produced a gradually increasing variety, until, at its base, we were in the Mahauwat Wady, and amongst the Desert flora, continued from Sinai up the Araba to this point. This wady, with its neighbour Zuweirah, by which we ascended to the plain of South Judæa, forms the subject of the botanical Paper by Mr. Lowne, already alluded to.

On Jebel Usdum I obtained the following Salsolaceæ:—Noëa spinosis-

sima, Moq.; Atriplex alexandrina, Boiss.; Salsola rigida, Pall., var. tenuifolia; S. tetragona, Del.; S. fœtida, Del.; S. inermis, Forsk.; and some others not determinable. The "mountain of salt" is, in fact, properly also a mountain of Salsolaceæ. Several of these are additions to the flora of Palestine.

Leptadenia pyrotechnica, Forsk., and Ochradenus baccatus, Del., grow to a large size at the mouth of the Zuweirah Wady. The latter was about fifteen feet high close to the Dead Sea. Zilla was here first seen in blow; it has a pretty little blossom like our Cakile maritima.

This southern end of the Dead Sea, as I learnt by bathing, is very shallow. In two places, here and at the Ghor es Safieh, the water was not above my knees for a couple of hundred yards out. Other parts of the sea, however, reach a depth of 200 fathoms.

During the ascent of Wady Zuweirah, to the westward plains of South Judæa, the following fresh species were collected:—Notoceras canariense, R. Br.; Enarthrocarpus lyratus, D. C.; Zollikoferia, ? sp.; Z. stenocephala, Boiss.; Lithospermum tenuiflorum, Linn.; Heliotropium rotundifolium, Sieb.; Ballota undulata, Fries.; Arnebia linearilobа, D. C.; and Plantago loefflingii, Linn. A large bulb, Urginea scilla, ? Steinh, now only in leaf, marks well the transition stage from the Ghor flora to that of the Judæan wilderness. Desert species, such as of Fagoniæ, Zygophylleæ, Retama, Acaciæ, Resedaceæ, Cucumis, Microrhynchus, Dœmia, Œrua, Forskahlea, and others, were here, for the most part, finally taken leave of. Most of these ascended about a third part of the ascent from the Ghor, or about 500 feet above the level of the sea. Several ceased at the altitude of the old Saracenic Fort, which may be taken roughly as about their upper limit. Above this, and on the Judæan plain, a great change took place. Unfortunately, a portion of this ride was performed in the dark, and I missed some of the transitional species. Ere long we found ourselves on rich land, arousing itself to a spring growth, although the most inclement season had not yet arrived. The need of water is, of course, everywhere apparent. Withered remains are even scarcer than in the desert; and the ground is often bare for considerable spaces, or with a few early patches of species to be presently mentioned.

While crossing this plain, with its thinly-scattered, humble flora, it was difficult to recall the existence of the luxuriant vegetation of the Ghor; and the transition was not merely from richness to poverty, but to a total variation of forms. The interesting species so eagerly sought for, and studied with such interest, had given place to an ordinary spring European vegetation. Hardly a bush and no trees occurred. Travelling still westwards, evidences of cultivation, that is to say, of the soil being "scratched" and sown, appeared. Soon after Bir es Seba, two days from the Ghor, we found ourselves among softly-swelling downs, covered with sowers and ploughers, but the general aspect of the country was monotonous in the extreme, as the chalk formation usually is.

The species first observed at the head of Wady Zuweirah, and onwards to Bir es Seba, were numerous, many of them just opening their flowers. Another fortnight later would have, perhaps, doubled the variety. The following were conspicuous:—Carrichtera vellæ, D. C.; Biscutella columnæ, Ten.; Euarthrocarpus lyratus, ? Del.; Silene dichotoma, Ehr.; S. hussoni, Boiss.; Helianthemum kahiricum, Del.; Astragalus sanctus, Boiss.; A. alexandrinus, Boiss.; Erodium cicutarium, Boiss.; Senecio coronopifolius, Del.; Scorzonera lanata, M. B.; Calendula arvensis, Linn.; Achillea santolina, Linn.; Anchusa milleri, Willd.; Cyclamen latifolium, Sibth.; Ajuga iva, Sch.; Marrubium alysson, Linn.; Salvia verbenaca, Linn.; S. controversa, Ten.; S. ægyptica, Linn.; Eremostachys laciniata, Linn., in leaf; Paronychia argentea, Lam., and Urginea undulata (?). Several of these are pretty little yellow, blue and pink annuals. When in full blow the sward must present a gay appearance.

We were now travelling on horseback, and I had no longer the same facilities for botanizing. The pace was usually too fast. My method was to keep well ahead till I reached some inviting point, and then dismount, and snatch up specimens with a rein over one arm. The result was that I was often far behind or galloping in hot pursuit. Sometimes I was lost altogether. Once, having missed my horse, I followed the tracks of another party, thinking they were my own gone far ahead. They took me to an Arab camp ten miles out of my way. The perpetual dismounting and remounting was at first very annoying to my horse and me. But

we got used to it. It would, however, require a botanical circus rider to get on and off with comfort as fast as fresh species occurred.

Several mosses and lichens were gathered on this march. The latter have been determined for me by the Rev. James Crombie. The mosses were Tortula muralis, Linn.; Bryum atropurpureum, W. & M.; and a Hepatic, Riccia lamellosa, Raddi. These mosses are British.

I spent as much time as I dared in digging up bulbs. Several of these were in flower, as Xiphion palestinum, Baker, a dwarf sweet-smelling iris, with good-sized flowers in tints of buff and pale blue, or French grey. Colchicum montanum, Linn., occurred in great plenty, white or pale mauve, and was very beautiful. Urginea scilla, Steinh., and Asphodelus ramosus, Linn., were most abundant, increasing westwards to Gaza. Bellevallia flexuosa, Boiss., a small plant, not unlike a dwarfed edition of our bluebell, is frequent, sometimes white, but normally blue. Ornithogalem umbellatum, Linn., appeared common; but I had to judge by its withered remains. Cyclamens were frequently found in blow.

At a marshy, saline swamp at Tel el Milh (Moladah), I gathered Spergularia marginata, Koch., and Cyperus longus, Linn. Cyperus lævigata, Linn., var. junciformis, was first met with. The Spurrey is very like our own larger-flowered salt-marsh species.

The abundance of land-snails on the small shrubs, chiefly on Anabasis articulata, must be alluded to. Helix seetzeni, Koch., was the commonest; but several other species occurred. Black-headed gulls come in from the Mediterranean to feast on them.

The bulbs of the larger sorts supply food for the wild boars with which this open country abounds. Where they managed to hide themselves by day we often wondered; but the uprooted soil afforded frequent evidence of their presence. An Urginea, probably U. undulata, was in especial demand. Urginea scilla almost covers square miles, growing sometimes to the exclusion of everything else. It appears to be a scourge to the fellahin. Great heaps of its bulbs, which sometimes reach the size of a man's head, are often met with; and lines of its growth are commonly left to mark off each cultivator's allotted portion.

The brilliant Anemone, A. coronaria, Linn., the "lily of the field,"

was picked in flower on the last day of the old year. Thymelæa hirsuta (Passerina), which I had gathered first at Brindisi and next at Mount Hor, was profusely common on this Judæan wilderness also. From Bir es Seba to Gaza, very few of our old desert friends remained; and these were chiefly of the Syrian type, as Caylusea, Dæmia, Alhagi, Peganum, Citrullus, Artemisia herba-alba, and Anabasis. Nevertheless these show well the nature of the vegetation of the debateable ground between the Tih desert and the fertile soil of lower Judæa.

The universal "rimth" of the desert (Anabasis) is called here by the Doheriyeh Arabs "shegar." In the Serbal range in Sinai this plant gives its name to a wady, Wady Rimthi. As a rule, however, the Arab names I obtained from the Sinai Bedouins differ from those recorded by other writers, who also usually differ amongst themselves; so that I do not, in all cases, attach much importance to these terms. Different tribes and places yield different synonyms, which are often, perhaps, due merely to the Bedouin's unfailing principle to be ready with an answer—a principle which, like his love for monotonous refrains, and some other characteristics, would seem, perhaps, to imply a community of descent with the Celtic race. I leave this suggestion for ethnologists to work out.

Travelling west, past Tel Abou Hereireh to Gaza, the following species occurred, in addition to those mentioned about Bir es Seba:—Malcolmia pulchella, Boiss.; Matthiola humilis, D. C.; Alyssum libyica, Vio.; Erucaria microcarpa, Boiss.; Capsella bursa-pastoris, Linn.; Polycarpon succulentum, Del.; Dianthus multipunctatus, Lab.; Silene rigidula, Sibth.; Ononis serrata, Forsk.; Hypericum tetrapterum, ? Fr.; Erodium hirtum, F.; Bupleurum, ?sp.; Carthamus glaucus, M. B.; Thrincia tuberosa, D. C.; Tolpis altissima, Pers.; Scorzonera alexandrina, Boiss.; Mandragora officinarum, Linn.; Withania somnifera, Linn.; Echium plantagineum, Linn.; Lamium amplexicaule, Linn.; Euphorbia exigua, Linn.; Paronychia nivea, D. C.; Andropogon hirtus, Linn., and Poa annua, Linn. Of these, a few, as Capsella, Lamium, Euphorbia, Hypericum, and Poa, are common British forms, and one or two other rarer Mediterranean forms just reaching the British islands.

At Gaza, in order to levy a tax on our purses, the Turkish authorities

detained us in quarantine. We had, in fact, been compelled to come to Gaza, instead of proceeding direct to Jerusalem from the Dead Sea. By the prompt interference, however, of Lord Dufferin, our British ambassador at Constantinople, to whom we telegraphed, we were released in four days, instead of a fortnight, and the detour and rest were to most of our pursuits decidedly beneficial. Without this delay my rapidly-made collection of the last four days would have been in hopeless confusion.

During my last day at Gaza, having liberty to leave quarantine ground, I gathered a good many species south of Gaza, which I had not before met with.

Gardens of fruit trees, olive groves, and enclosures fenced by the prickly pear, reached our camp from the northern or Gaza side. On the seaward we were hemmed in by high sandhills, the vanguard of an ever-advancing column, driven eastwards by the prevailing winds. Some laborious journeys across this waste of sands, often three or four miles in breadth inland from the sea, impressed them painfully on my memory. They yielded few species, being, as a rule, shifting and barren. I may mention Silene succulenta, Forsk.; Scrophularia xanthoglossa, Boiss.; Euphorbia terracina, Linn. These grew well out on the dunes.

At an estuary about four miles south of Gaza, and up a low, flat wady leading to it, I obtained some good plants. The following are the most interesting:—Brassica tournefortii, Gou.; Neurada procumbens, Linn.; Astragalus aleppicus, Boiss.; A. macrocarpus, D. C., not in fruit; Medicago laciniata, All.; Ononis natrix, Linn. var.; Anagyris fœtida, Linn.; Acacia albida, Del.; Prosopis stephaniana, Willd.; Xanthium strumarium, Linn.; Artemisia monosperma, Del.; Centaurea araneosa, Boiss.; C. pallescens, Del.; Atractylis prolifera, Boiss.; Linaria hœlava, Forsk.; Anchusa ægyptica, Lehm.; Prasium majus, Linn.; Andrachne aspera, Linn.; Ricinus communis, Linn.; Boerhaavia verticillata, Boiss.; Plantago albicans, Linn.; Euphorbia peploides, Gou.; Rumex spinosus, Camp.; Salsola inermis, Forsk.; Cyperus schœnoides, Grisel.; C. rotundus, Linn.; Pennisetum cenchroides, Rich. Some of these were old desert friends; and the Castor oil, Neurada, and tropical Boerhaavia point to the great heat of Gaza.

The trees about Gaza were chiefly date-palms, olives, sycamore-fig (Ficus sycamorus), caroub (Ceratonia siliqua), and the fig. A very handsome tamarisk (T. articulata, Vahl.) reached a height of forty feet, and had bright green foliage, very refreshing after the lifeless hues of the desert. The olives were apparently of enormous age. They usually had unbranched trunks, or forked once, to about seven or eight feet in height; and then a leafy, branched canopy, browsed below to a level height by cattle. Their average height was twenty-five to thirty feet. Old trees had often mere shells of their trunks remaining. The two largest I saw, which I measured, were a few miles north of Gaza, with a girth of eighteen and twenty feet respectively at two feet from the ground. This size was maintained, or nearly so, until the trunk forked.

VIII. Gaza to Jerusalem.

At Ascalon I gathered Calycotome villosa, Linn., a yellow-flowered, spiny, shrubby, leguminous plant, very difficult to preserve specimens of.

Along the Mediterranean seaboard the chief crop appeared to be lentiles. Beanstalks a foot and a-half high were seen in the first week of January.

Some of the commonest British species, as Capsella bursa-pastoris, Silene inflata, Convolvulus arvensis, Rumex obtusifolia, and Urtica diöica occurred along here; also a handsome tree was introduced from farther east, Melia azedarach, or the "Pride of India," grew along the enclosures or by the villages. It is a deciduous tree, and only bore fruit at this season. We rode along a beaten track amongst the cultivated land, often detouring as our fancies suggested, and sometimes, for a space, we were on what is called in this country a road.

There are only two real roads in Palestine which can be passed on wheels: an infamous one from Jaffa to Jerusalem, and another perfect road, kept in order by a French company, from Beyrout to Damascus.

Along the hedge-rows of prickly pear the chief plants were Lycium europæum, Linn.; Rubia olivieri, A. Rich.; Ephedra alata, Dcne.; Aspa-

ragus aphyllus, Linn.; A. acutifolius, Linn.; Bryonia, Prasium, and Convolvulus.

At Yebdna, and thence to Jaffa, Narcissus tazetta, Linn., was in flower. Some damp, low-lying patches, on sandy soil, just inside the broad belt of sandhills, were white with it. Other species were the fetid Ruta graveolens, Linn., Erodium (? sp.), E. bryoniæfolium (?), Retama retam, Forsk.; Lithospermum callosum, Linn.; Echiochillon fruticosum, Desf.; Thymus capitatus, Linn.; Lavandula stœchas, Linn., and Rhamnus punctata, Boiss. The Retam was in flower, and very pretty, white and purple, with a sweet smell. It is a species of broom. Lawsonia alba, Linn., "henna," was seen several times, but usually here, as at Akaba, about enclosures. At Enjedi it is, I believe, abundant, but is, no doubt, a relic of ancient gardens. It is native much farther east.

In the gardens by the hotel at Jaffa, for we had now reached that seat of early civilization, were some very interesting plants, by whom collected or from whence I did not ascertain. Some Sinaitic and Ghor species were observed. The handsome trailing pea, Dolichos lablab, which I found in the Ghor es Safieh, was there; a plant widely cultivated and eaten in hot countries, but perhaps originally a native of India. The Gomphocarpus of Sinai was there also, differing, however, in size, being shrubby almost, and about six feet high. In the desert it averages from a foot to a foot and a-half. I could see no other difference, and good soil would suffice for increased size. A purple, woolly lavender, very showy and handsome, just found the day previously in the wild state, was here also. This was Lavandula stœchas, Linn. Castor oil, Echaverias, Acaciæ, and Mimosæ, with oranges, bananas, india-rubber trees, Eucalyptus, fan palms, and Mesembryanthemum were here, amongst others unknown to me. I was especially interested to see here the Boucerosia from Mount Hor. The gardens at Jaffa were well supplied with most excellent oranges.

Between Ramleh (a few miles from Jaffa) and Jerusalem, during an ascent of over 2000 feet, many fresh species occurred. The chief change in the vegetation lay in the great increase of low, shrubby forms on the limestone hills and terraces. I had little time to botanize; but,

with hard galloping to make up for delays I secured several sorts in good condition. An oak, Quercus coccifera, Linn., and the handsome, large-leaved arbutus now in full flower, Arbutus andrachne, Linn., were two conspicuous bushes (for they are rarely permitted to attain large size) characteristic of the rocky region above the plain of Ramleh. A large daisy, Bellis sylvestris, Cyr., similar except in size to our own Bellis perennis, was in flower. The handsome caroub, or locust tree, was very frequent. Its rich dark-green pinnate foliage is well-known to travellers in southern Europe. At Kirjath Jearim, a solitary date-palm occured; and I was informed at Jerusalem that a still-remaining clump of pines exists near this; no doubt, Pinus halepensis, Linn., which I afterwards found at Jerusalem. Maidenhair, Ceterach, and the fragrant Cheilanthes were the ferns observed, chiefly amongst the limestone clefts above Bab el Wad. A handsome sage, Salvia triloba, was in flower; and several of the labiates, as Phlomis, ? sp.; Micromeria barbata, B. & K.; M. myrtifolia, Boiss.; M. nervosa, Desf.; and Teucrium polium, Linn., were gathered. Bryonia syriaca, Boiss., and a beautiful clematis, with dull purple flowers, C. cirrhosa, Linn., trailed by the roadside on walls and fences. Calycotome, Anagyris, and Ephedra were not uncommon. A few others were Reseda alba, Linn.; Malcolmia crenulata, Boiss.; Thlaspi perfoliatum, Linn.; Erodium moschatus, W.; Thelygonum cynocrambe, Linn.; Ononis natrix, Linn.; Inula viscosa, Boiss.; Sherardia arvensis, Linn.; Alkanna tinctoria, Tausch.; and Onosma syriaca, Lab. Most of these were common about Jerusalem and Bethlehem.

At Jerusalem, we came in for an unusually heavy fall of snow, lasting from the 20th to 25th of January. There was, therefore, little to be done in botany about the Holy City. Fortunately, we had accomplished our pilgrimage to Jericho before the snow set in, which gave me an opportunity of comparing the northern with the southern Ghor or Hollow of the Dead Sea.

About Jerusalem, but especially along the tiny aqueduct between the Pools of Solomon and Bethlehem, some plants were in flower or in an identifiable state:—Erodium malacoides, Linn.; E. gruinum, Linn.; Pistacia palæstina, Boiss.; Sedum, sp. (S. altissimum, Poir. ?), Tordylium brachy-

carpa, Boiss.; Torilis trichospermum, Spr.; T. leptophylla, Rich.; Pimpinella cretica, Poir.; Galium judaicum, Boiss.; Pisum fulvum, Sch.; Lathyrus blepharicarpus, Boiss.; Carduus argentatus, Linn.; Urospermum picroides, Desf.; Crepis senecioides, Del.; Hyoscyamus aureus, Linn.; Anchusa milleri, Willd.; Onosma, Cyclamen, Plantago lagopus, Linn.; Viscum cruciatum, Linn.; Euphorbia aulacosperma, Boiss.; Gagea reticulata, R. & C.; Agrostis verticillata, Willd.; Avena sterilis, Linn.; and some common British plants, such as Nasturtium officinale, Cerastium glomeratum, Geranium molle, Torilis nodosa, Rubus discolor, Veronica anagallis, and V. beccabunga, will serve to give botanists an idea of the spring flora of Jerusalem.

Jerusalem, 2400 feet above sea-level, falls within Boissier's Plateaux subdivision of the Oriental Region. His flora deals with the countries from Greece to India, through a width of about twenty degrees of latitude north of the tropics. He divides these into (1) "Mediterranean," (2) "Middle Europe," (3) "Oriental," and (4) "Région du Dattier," or Desert. The Oriental is subdivided into Plateaux, Aralo-Caspian, and Mesopotamian. Jerusalem and Damascus, and the regions round and above these cities, lie in the Plateaux subdivision. So, also, would the upper parts of Sinai; while the desert regions come under his Région du Dattier.

The climate of Jerusalem is milder and more Mediterranean in character than most of the Plateaux sub-region. The date-palm, though not native, nor able to ripen its fruit, can exist and grows to goodly dimensions, as is evidenced by one well-known tree. The prickly pear is naturalized. Nevertheless, though olives, apricots, grapes, tomatoes, and figs thrive well at Jerusalem, oranges, lemons, bread and water melons will not succeed, though ripening their fruit admirably at Jaffa. Apples, pears, and strawberries have all been unsuccessfully tried at Jerusalem. Nectarines and pomegranates do fairly well. To Mr. Max Aunger, an intelligent resident at Jerusalem, I am indebted for these details.

Cupressus sempervirens, L., var. pyramidalis, the funeral cypress, attains a good size in the esplanade between the mosques of Omar and El Akhsa; but far finer specimens were afterwards seen at Smyrna and Constantinople, especially at the former place. The Prince of Wales' tree

Pinus halepensis, Linn., pointed out as that which the Prince camped under, is the finest tree near Jerusalem. It is about fifty or sixty feet high, and well furnished. Smaller pines of this species occur at the Armenian convent.

An interesting Jerusalem species is the red-berried mistletoe, Viscum cruciatum, Linn., parasitic on the olive, and known elsewhere only sparingly in southern Spain. Mr. Armstrong, who, when his surveying duties permitted, was always ready throughout our tour to lend me a helping hand, brought me specimens from the Valley of Jehoshaphat.

IX. Jericho and Northern Ghor.

On the 14th January we went down the Jordan valley from Jerusalem. Immediately after leaving Mount Olivet, I found abundance of Androcymbium (Erythrostictus, Boiss.) palæstinum, Baker, first seen in the Araba above the Ghor. It is a stemless, white-flowered Colchicaceous plant, rather leafy, and with flowers of no great beauty. I mention it particularly because that careful observer, Mons. Barbey, mentions that, while Roth formerly found this plant near Jerusalem, he was unable to rediscover it. I am thus able to confirm Roth's record. Mons. Barbey's visit (April 3) was too late for this species. His work, "Herborization au Levant," Lausanne, 1882, must be referred to by all who want fuller information on the botany of this neighbourhood.

Descending even a slight distance eastwards from the heights of Jerusalem, the climate at once improves. Bethlehem and the neighbourhood of Solomon's Pool are, judging from plant life, milder than Jerusalem. We gradually travelled from midwinter into spring. Several species, lost sight of till now, since we climbed from the Ghor by Wady Zuweirah, now reappeared as we descended into this remarkable depression. Some of these occurred no doubt since, but not in flower. Fumaria, Carrichtera, Biscutella, Malcolmia, Erucaria, and species then quoted, may be mentioned. Fresh forms occurred, as Hypecoum procumbens, Linn.; Capsella procumbens, Linn.; Neslia paniculata, Linn.; Hippocrepis unisiliquosa, Linn.; Hymenocarpus circinnatus, Savi.; Astragalus callichrous, Boiss.; A.

sanctus, Boiss., var.; Trigonella arabica, Del.; Matricaria aurea Boiss.; Chrysanthemum coronarium, Linn.; Veronica syriaca, K. & S.; Arnebia cornuta, R. & M.; Asperugo procumbens, Linn.; Emex spinosus, Campd.; Muscari racemosum, Will.; Lamarckia aurea, Moench. These are mostly bright-coloured spring flowers. The Veronica is a very pretty little blue and white species. Hypecoum is like a yellow Fumaria. Others, chiefly Linariæ (L. hælava, &c.), were very gay in places as the temperature increased with our descent.

At about sea-level, some desert species began to occur, as Zygophyllum album Linn. (in flower); Prosopis stephaniana, Willd.; Reseda pruinosa, Del.; Roetama retam, Forsk.; Ochradenus baccatus, Del.; Tamarix gallica, Linn., var.

We were again amongst the marls, which are most conspicuous at about the middle height, between the levels of the Mediterranean and the Dead Seas. The flora of this part of the Jordan valley was, to a certain extent, a repetition of that of the southern Ghor, with expected alterations. Many of the most interesting tropical species were missing; and others, of familiar types, took their place. Widespread European species were much more numerous. Common British species of Draba, Capsella, Thlaspi, Nasturtium, Rubus, Helosciadium, Malva, Galium, Veronica, Mentha, Solanum, Lythrum, Cichorium, Verbena, and Euphorbia, were all met with in about a total of five species in the northern Ghor to one in the southern. Nor did theseason at Jericho seem to be ahead of that at Es Safieh.

Jericho and its neighbourhood have been amply described by many able writers; and its botany has been well illustrated by Mons. Barbey in his work already referred to. This latter visitor has not, however, corrected one statement repeatedly made by various travellers—that of the ancient grove of date-palms extending for several miles around Jericho there is no existing representative. There is one good-sized date-palm, twenty-five feet high, I should say, at Gilgal.

The characteristic species of the southern Ghor growing here were Zizyphus spina-christi, Linn.; Balanites ægyptiaca, Del.; Loranthus acaciæ, Zucc.; Calotropis procera, Willd.; and, in a less degree, Populus euphratica, Oliv.; the latter being very abundant along the Jordan. This

poplar is remarkable for the variability in shape of its leaves, in the younger trees especially. In full-grown old trees, which are, however, rarely met with, they become more uniform. Tamarisks and the Zukkum (Balanites), or false balm of Gilead, were abundant about Jericho. An acacia near Ain es Sultan was, I think, A. albida, Del., gathered previously at Gaza. It was a stunted bush; and all the acacias of Sinai and Es Safieh had disappeared, except the Prosopis stephaniana, their near relative. This is a small, untidy little shrub, which thrives best in wet, saline places, and bears a very peculiar pod, swollen, solid, irregularly shaped, and so like a gall or deformity of some kind that it was not until I had several times extracted the seed I could believe it to be natural.

Bananas, oranges, and a few sugar-canes are cultivated in the Arab gardens at Gilgal, the modern Jericho.

The river Jordan was considerably swollen, and so muddy that a plunge in its waters did not look inviting. However, Laurence and I swam it, and set foot on the "other side of Jordan." It was about thirty yards across, and deep, with a current of considerable strength.

We returned to Jerusalem by Marsaba, where we camped on the night of the 16th. This was, unhappily, our last experience of the most enjoyable kind of Eastern life, camping out. Our intended expedition by Tiberias and Merom, through northern Palestine, ending in Beyrout, was stopped by heavy snow. Before closing, I have to mention the species gathered at Jericho which were not previously met with:—Ranunculus asiaticus, Linn.; Matthiola oxyceras, D. C.; Saponaria vaccaria, Linn.; Silene palæstina, Boiss.; Arenaria picta, Fengl.; Rhus oxyacanthoides, Dum.; Ammi majus, Linn.; Aizoon hispanicum, Linn.; Ononis antiquorum, Linn.; Evax contracta, Boiss.; Amberboa lippii, D. C.; Hedypnois cretica, Boiss.; Hagioseris, ? sp.; H. galilææ, ? Boiss.; Picris, ? sp.; Orobanche ægyptiaca, Pers.; Linaria albifrons, Sibth.; L. micrantha, Cav.; Cuscuta, ? sp.; C. palæstina, Boiss. ?; Convolvulus siculus, Linn.; Vitex agnuscasti, Linn.; Phalaris minor, Retz.; Schismus marginatus, P. de B.; Bromus madritensis, Linn.; Kœleria phleoides, Pers. The Orobanche was a lovely bright blue species in full flower. The Rhus is a red-berried thorn, very like hawthorn, but with flattened berries, and

minute flowers. Captain Burton has found this species as far south as lat. 26°, in Midian, at about 4000 feet above sea level. It is very strange that it does not appear to occur in Sinai. Ononis antiquorum was an erect shrub about five or six feet high, with a few long, rigid, slender, spiny branches. Ranunculus asiaticus is so like Anemone coronaria at a little distance that it was not at first distinguished from it. Both are of a gorgeous scarlet colour. The Vitex, one of the very few northern representatives of the tropical verbenaceæ, is a straggling shrub, with dull blue flowers, of no particular beauty.

Young fragments, chiefly of Cruciferæ, Leguminosæ, and Umbelliferæ, were often gathered; but for these orders the season was, as a rule, too little advanced.

At Marsaba there is a date-palm tied up and supported in the court-yard of the convent, which the monks relate was planted by St. Saba (A. D. 490). This tree is of interest, however, since I believe it is a fact that the fruit which it bears is always stoneless.

On the 17th we reached Jerusalem. A week later, we left for Beyrout, where our party divided, Professor Hull and his son returning homeward. Major Kitchener had left us near Gaza; and we had parted with Mr. Armstrong at Jerusalem. Laurence and I, however, faced the heavy snow, and succeeded in crossing Lebanon and Hermon to Damascus, by the admirable French road, visiting Baalbek on the way. On all this country the snow lay in greater or lesser thickness; and as I was hindered thereby from making any collections or observations on natural history, I brought my herborization to a close.

LIST OF SPECIES.

NOTE.—An asterisk (*) is placed in front of the species which do not appear to have been previously found in Palestine, about seventy in number, omitting mosses.

RANUNCULACEÆ.

Clematis cirrhosa, Linn.—Jericho, Ramleh and Jerusalem. Also at Smyrna.

Anemone coronaria, Linn.—Tel Abou Hereireh and Gaza. In flower last day of December.

Ranunculus asiaticus, Linn.—Jericho. Flowering in middle of January.

MENISPERMACEÆ.

Cocculus leœba, D. C., var. "approaches C. villosus, but petals entire, fl. ♀" (Oliver).—Trailing over acacia trees (A. tortilis) in the Ghor el Feifeh and Es Safieh, but not common.

**C. leœba*, D. C., var. fl. ♂.—On "Nubk" (Zizyphus), on the east side of the Arabah, near El Taba. This plant, with a woody stem a quarter of an inch in diameter or more, and veined ovate-orbicular leaves, had a very distinct appearance from the foregoing wiry climber, whose leaves were smaller and narrower. I think it may be found that there are two species occurring. Cocculus leœba ranges from tropical Arabia, Nubia and Abyssinia to Egypt and to Sinai: an addition to the flora of Palestine. The species appears in the "Flora Orientalis" amongst the *addenda* to the fourth volume.

BERBERIDEÆ.

Leontice leontopetalum, Linn.—Leaves appearing between Medjel and Jaffa in the beginning of January.

PAPAVERACEÆ.

Glaucium arabicum, Fres.—Sinai, from Wady Lebweh to Wady Zelegah. Confined, so far as is known, to Sinai. Leaves only showing in November.

Hypecoum procumbens, Linn.—Khan el Akhma, between Jericho and Jerusalem.

FUMARIACEÆ.

Fumaria parviflora, Lam.—Ramleh to Jerusalem; Jericho.

F. micrantha, Lag.—Wady Zuweireh to Bir es Seba.

F. capreolata, Linn.—Gaza.

CRUCIFERÆ.

Morettia canescens, Boiss.—Jebel Abou Kosheibeh, near Mount Hor; Wadies Lebweh, Barak and Es Sheikh; El Taba in the Araba. Recorded from Arabia Petræa (Boiss.) and east of Gilead (Tristram).

Matthiola incana, Linn.—Coast at Jaffa. A garden escape ?.

**M. humilis*, D. C.—Tel Abou Hereireh to Gaza. A rare species; known only from Egypt, about Alexandria and Rosetta. My specimens were determined by Mons. Boissier. An addition to the flora of Palestine.

M. oxyceras, D. C.—Jericho.

Eremobium lineare, Del.—Wady Arabah and Wady Ghuweir; Wady Zuweirah.

Farsetia ægyptiaca, Turr.—Frequent in Sinai, and along the Araba to the Dead Sea.

Nasturtium officinale, R. Br.—Bethlehem and Jericho.

**Sisymbrium erysimoides*, Desf.—Ghor es Safieh and Jericho. Has been found in Sinai. A desert species, with a wide range east and west. An addition to the flora of Palestine.

S. irio, Linn.—In the same localities as the last.

Malcolmia pulchella, Boiss.—From Tel Abou Horari westwards.

M. crenulata, Boiss.—Bethlehem and Jericho; between Ramleh and Jerusalem. These two pretty little annuals appear to be confined to Syria and Palestine.

Alyssum campestre, Linn.—Jericho.

A. (*Koniga*) *libyca*, Viv.—Ghor es Safieh; Bir es Seba to Gaza; Ramleh to Jerusalem.

Erophila vulgaris, D. C., (Draba verna).—Jerusalem to Jericho.

Notoceras canariense, R. Br.—Ghor es Safieh; Wady Zuweirah; Jericho.

Anastatica hierochuntina, Linn.—Plentiful about Akaba, and above it westwards by the Hadj road, and south-west to Jebel Hertih; Ghor es Safieh.

Biscutella columnæ, Ten.—Jericho; Wady Zuweirah to Bir es Seba.

Thlaspi perfoliatum, Linn.—Jericho; Bethlehem; Ramleh to Jerusalem.

Isatis (? sp.), *I. aleppica*, Scop. ?—Bethlehem.

Capsella bursa-pastoris, Linn.—Bir es Seba, Jericho, &c.

C. procumbens, Linn.—Jericho.

Erucaria aleppica, Gært.—Ghor es Safieh and north-east end of the Wady Araba.

E. microcarpa, Boiss.—Jericho; Ghor es Safieh; plain of S. Judæa, frequent.

Neslia paniculata, Linn.—Jericho.

Moricandia sinaica, Boiss.—Wady Elain in Sinai.

M. dumosa, Boiss.—Wady Zelegah to Wady Elain; Petra, Mount Hor, Wady Ghurundel, and elsewhere east of the Araba. Only known previously from the Tih.

{ *Diplotaxis harra*, Forsk.—Ghor es Safieh.
{ *D. pendula*, D. C.—Petra and Ghor es Safieh. A very variable species. This and the previous species have been thus distinguished among my specimens by M. Boissier. The names are, I believe, synonymous; but the Petra plants had the fruits much more decidedly pendulous.

CRUCIFERÆ—*continued.*

Brassica nigra, Linn.—Gaza.

B. ? sp., *B. deflexa*, Boiss. ?—Bethlehem. Specimens insufficient.

B. tournefortii, Gou.—Gaza. [Several indeterminable Crucifers, chiefly Brassicæ, were brought home.]

Sinapis alba, Linn.—Jericho.

S. arvensis, Linn.—Tel Abou Hereireh to Gaza.

Carrichtera vellæ, D. C.—Wady Zuweirah to Bir es Seba; Jericho. This species has the peculiar habit of keeping its cotyledon attached even while in flower.

**Enarthrocarpus lyratus*, D. C.—Bir es Seba to Gaza, in several places; at Jericho. Known from Greece, Lower and Middle Egypt. An addition to the flora of Palestine.

E. ? sp. (probably *E. strangulatus* Boiss.), but specimens imperfect. Wady Zuweirah to Bir es Seba.

Zilla myagroides, Forsk.—Frequent in Sinaitic peninsula. In flower the last week of December at the Ghor es Safieh.

CAPPARIDEÆ.

Cleome arabica, Linn.—Debbet er Ramleh, Wady Hamr, and Wady Nusb, on the west side of Sinai, and at Wady Zelegah, between Mount Sinai and Akaba.

C. trinervia, Fres.—Wadies Berah and Lebweh.

C. droserifolia, Del.—Wady Elain; Akaba; ? Ghor es Safieh. In flower and fruit in November, as was C. arabica. C. trinervia was barely showing its leaves. "Probably the same as C. quinquenervia, D. C.," Lowne.

Capparis spinosa, Linn., var. γ *ægyptiaca*, Boiss.—Wadies Zelegah and Elain, &c. Much more glaucous and smaller (usually trailing) than the following. In Wady Elain, where the two occur together, they look widely different. The type occurs about Jerusalem.

C. galeata, Fres.—Cliffs above Wady Sarawat, and with the last. This species is sometimes an erect bush. At the base of Jebel Aradah, I measured one 8 ft. high.

RESEDACEÆ.

Ochradenus baccatus, Del.—Frequent in Sinai from Wady Ghurundel ("Elim") to the Dead Sea.

Reseda pruinosa, Del., = *R. amblyocarpa*, Fres. ?—Wady Elain to Akaba, and thence along the Araba to the Dead Sea.

R. alba, Linn.—Jericho; Ramleh to Jerusalem.

R. stenostachya, Boiss. ?—Wady Elain. Too young to be certain about.

Caylusea canescens, St. Hil.—Frequent in Sinai, and thence to the Dead Sea, along the Araba. From the Ghor across to Bir es Seba in two or three places. An addition to the flora of Palestine.

CISTINEÆ.

Cistus villosus, Linn.—Medjel to Jaffa.

Helianthemum lippii, Pers,—Frequent in the upper parts of Sinai, and along the edge of the Tih to Akaba; Mount Hor; Gaza. A variety, with larger pedunculate flowers, occurs at Jebel Abou Kosheibeh. A late summer flowerer, almost all dead in December.

H. kahiricum, Del.—Wady Zuweirah to Bir es Seba. A very early flowerer, just appearing at the end of December.

SILENEÆ.

Dianthus multipunctatus, Ser.—Wady Ghurundel (Edom) and Mount Hor; plain of Judæa from Wady Zuweirah to Gaza. Not found so far south previously.

D. sinaicus, Boiss.—Mountains about Wady es Sheikh. Confined to Sinai.

Saponaria vaccaria, Linn.—Jericho.

Gypsophila rokejeka, Del.—With Dianthus sinaicus at Zibb el Baheir in Wady Lebweh; Wady Berah; Jebel Abou Kosheibeh; Ain Abou Weiridah in the Arabah,

G. (*Saponaria*) *hirsuta*, Lab., δ *alpina* (Boiss.)—Summit of Jebel Catharine at 8500 feet. One of the very few species of the higher Mediterranean alps found in Sinai. This particular form is confined to Lebanon, Hermon, Makmel and the present station.

Silene dichotoma, Ehrh.—Wady Zuweirah to Bir es Seba.

S. atocion, Murr., *S. ægyptiaca*, Linn.—Ramleh to Jerusalem; Jericho.

**S. hussoni*, Boiss.—Between Bir es Seba and Tel Abou Hereireh. Coming into flower at the end of December. Mons. Boissier, who named this species for me, records it from a single locality, "Ouadi Sannour deserti Ægyptiaco-Arabici." An addition to the flora of Palestine.

S. inflata, Sm.—Gaza.

S. palæstina, Boiss.—Jericho.

**S. colorata* Poir.—Jericho. Not included in the "Flora Orientalis," but found in Crete according to Nyman. An addition to the flora of Palestine.

S. succulenta, Forsk.—Sands at Gaza.

Buffonia multiceps, Dcne.—Near the summits of Jebel Catharine and Jebel Musa; Zibb el Baheir at the head of Wady Lebweh. Confined to Sinai.

Arenaria (*Alsine*) *picta*, Sibth.—Jericho.

A. graveolens, Schreb.—Summits of Jebel Musa and Jebel Catharine; top of Zibb el Baheir, in Wady Lebweh.

Stellaria media, Linn.—Gaza.

Cerastium glomeratum, Thuill.—Bethlehem.

Spergula pentandra, Linn.—Jericho and Ghor es Safieh. Noticed previously at Gaza.

Spergularia marginata (Koch.)—Saline swamps at Tel el Milh (Moladah).

PARONYCHIACEÆ.

Polycarpœa fragilis, Del.—Frequent in the lower parts of Sinai, and along the Arabah Valley to the Ghor es Safieh.

P. (*Robbairea*) *prostrata*, Dcne.—Same range as last, but less common. At Jebel Usdum. Plentiful at Debbel es Ramleh, in Sinai.

**Polycarpon succulentum*, Del.—At Jericho, and between Tel Abou Hereireh and Gaza. An addition to the Palestine flora.

Herniaria hemistemon, J. Gay ?—Jericho. Too young to be certain about.

**Paronychia nivea*, D. C., = *P. capitata*, Lam., not Koch.—About Bir es Seba. Not included in the Flora Orientalis, but found as far east as Greece, according to Nyman. An addition to the flora of Palestine.

P. argentea, Lam.—Mount Hor. A variety of this species occurred at a considerable elevation. Gaza, Jericho.

**P. desertorum*, Boiss.—Ain Musa, near Suez; Wady Ghuweir, on the east or Edomitic side of the Arabah. Perhaps only a form of P. arabica, Linn. An addition to the flora of Palestine.

Gymnocarpum fruticosum, Linn.—Common in Sinai and along the Arabah, especially in the Edomitic valleys.

**Sclerocephalus arabicus*, Boiss.—Ghor es Safieh. A desert species found in Sinai. An addition to the flora of Palestine.

Pteranthus echinatus, Desf.—Jericho.

CERATOPHYLLEÆ.

Ceratophyllum demersum, Linn.—Drifting in the Gulf of Suez at Ain Musa.

MOLLUGINEÆ.

Glinus lotoides, Linn.—Wadys Nusb and Sarawat. Not noticed hitherto in Sinai.

TAMARISCINEÆ.

Tamarix gallica, Linn., var. *nilotica*, Ehr., et *T. nilotica*, Ehrh.—Frequent in Sinai to the Dead Sea, and in the Jordan Valley. Var. *mannifera*, Ehr., occurs also, as on the summit of Jebel Usdum and Wady Zelegah.

**T. articulata*, Vahl.—Between Ramleh and Jerusalem; ? introduced. A handsome tree about Gaza, thirty-five feet high, belongs, I believe, to this species. An addition to the flora of Palestine.

Reaumuria palæstina, Boiss.—Common in Sinai. This form has been recorded only from the Dead Sea, but probably, as suggested by Lowne, it is identical with *R. hirtella*, Jaub., *R. vermiculata*, Linn., the name by which the Sinai plant has been collected. Flowers were obtained in November.

HYPERICINEÆ.

Hypericum tetrapterum, Fr. *forma*.—Between Gaza and Tel Abou Hereireh. A small prostrate form, but not in flower.

MALVACEÆ.

Malva rotundifolia, Linn.—Wadies Nusb and Sarawat; Jebel Musa; Petra; very abundant about Tel el Milh and Bir es Seba.

M. sylvestris, Linn.—Jericho.

Abutilon muticum, Del.—Ghor el Feifeh and Ghor es Safieh.

A. fruticosum, G. & P., (*Sida denticulata*, Fres.)—Wady Elain in Sinai, and Wady Ghurundel in Edom.

TILIACEÆ.

Corchorus trilocularis, Linn.—Ghor es Safeih and Feifeh, frequent.

GERANIACEÆ.

Geranium tuberosum, Linn.—I gathered the tuberous roots of, I believe, this species, like small flattened potatoes, on the summit of Mount Hor.

G. molle, Linn.—Bethlehem.

Erodium cicutarium, Linn.—From the Ghor across Judæa to Gaza, and at Jericho.

E. moschatum, Linn.—Jericho; Ramleh to Jerusalem.

E. gruinum, Boiss.—Bethlehem.

E. laciniatum, Cav.—Jericho.

E. malacoides, Linn.—Jericho and Bethlehem.

E. hirtum, Forsk.—Frequent in Sinai; in the Araba to the Ghor, and in the Edomitic valleys; Tel abou Hereireh to Gaza.

E. glaucophyllum, Ait.—Wadies Sudr and Ghurundel (Elim), on the north-west side of Sinai.

E. (?) sp. *bryoniæfolium*, Boiss.?—Medjel to Jaffa.

Monsonia nivea, Dcne.—Debbet er Ramleh; Wadies Lebweh and Berak; Ain ahou Weirideh and near the Ghor in the Arabah.

ZYGOPHYLLEÆ.

Tribulus terrestris, Linn.—Wadies Lebweh and Berak; W. Ghuweir in Edom; Ghor.

T. alatus, D. C.—Wady el Tihyeh and Jebel Hirteh.

Fagonia glutinosa, Del.—Debbet er Ramleh; Wadies Ghurundel (Elim) and W. Sudr.

F. myriacantha, Boiss.—Wadies Lebweh, es Sheikh, Haroun, and Arabah.

F. kahirica, Boiss.—Ghor es Safieh.

F. grandiflora, Boiss.—Wady Arabah, near the Ghor.

F. arabica, Linn.—Debbet er Ramleh to Akaba, common in Sinai.

F. cretica, Linn. var.—Ghor es Safieh and Wady Ghuweir.

ZYGOPHYLLEÆ—*continued.*

Fagonia cretica, Linn., "var. ramulis subteritis incano-puberalis," Oliver.—Wady Elain and Jebel Usdum. As deserving of special distinction as several of the above. Fresh varieties turn up in every wady, and it is hopeless to endeavour to separate the numerous described varieties. It would perhaps be preferable to follow Anderson in re-uniting them under the general name. The above are Mons. Boissier's determinations of my specimens.

Zygophyllum dumosum, Boiss.—Wady Hessih and Jebel Hirteh to Akaba.

**Z. simplex*, Linn.—Ghor es Safieh. An addition to the flora of Palestine.

Z. album, Linn.—Wady Ghurundel (Elim) and elsewhere; very frequent in Sinai and about the Dead Sea. Between Jerusalem and Jericho at about sea level.

Z. coccineum, Linn.—Wady Elain.

Seetzenia orientalis, Dcne.—Debbet er Ramleh and Wady Hamr.

Peganum harmala, Linn.—Wadies Elain, es Sheikh, Berah and Lebweh; summit of Jebel Musa and Ghor es Safieh.

Nitraria tridentata, Desf.—Ain Musa, Wady Ghurundel (Elim), Wady es Sheikh, Akaba, and by the Dead Sea.

RUTACEÆ.

Ruta graveolens, Linn., (*R. chalepense*, Linn.)—Jericho; Medjel to Jaffa.

R. (*Haplophyllum*) *tuberculatum*, Forsk.—Wady Zelegah to Wady Elain; Akaba; frequent in Edomitic wadies; Ghor es Safieh. A hairy form occurs at Wady Lebweh and Debbet er Ramleh. This plant has a most sickening and persistent smell.

SIMARUBEÆ.

Balanites ægyptiaca, Del.—Jericho, and Ghor es Safieh and Feifeh.

TEREBINTHACEÆ.

Rhus oxyacanthoides, Dum.—Several bushes between Jericho and the Jordan, the 'arour' of Bedouins. Has much the appearance of our hawthorn, but with inconspicuous flowers, and the red berries flattened.

Pistacia palæstina, Boiss.—Bethlehem; summit of Mount Hor, at an estimated height of 4400 feet. Not found so far south previously.

Zizyphus spina-christi, Linn.—Wady Nusb; Akaba; Wady Ghuweir. Abundant about Jericho and in Ghor el Feifeh, and Ghor es Safieh.

Rhamnus punctata, Boiss., ? var. *microphylla*, Boiss.—Medjel to Jaffa. Barren.

R. punctata, Boiss., and *R. palæstina*, Boiss. ?—Medjel to Jaffa.

R. (?) sp., *R. oleoides*, Linn. ?—In several places in a barren condition in the Ghor es Safieh. Leaves small and deciduous. Shrub six to ten feet high, and called by the Bedouins "Seisaban."

LEGUMINOSÆ.

Anagyris fœtida, Linn.—Gaza; Ramleh to Jerusalem.

Crotalaria ægyptiaca, Bth.—Wadies Nusb and Sarawat.

Lupinus reticulatus, Desv.—Between Ramleh and Jerusalem, and at Ascalon, the eastern limits of the species.

L. termis, Forsk.—About Medjel, Gaza and Jaffa. Cultivated.

Lotononis lebordea, Benth., (*L. dichotoma*, Del.)—Wadies Lebweh, Berah, es Sheikh, and Arabah.

Calycotome villosa, Linn.—Sand hills at Ascalon; Medjel; Ramleh to Jerusalem.

Genista (*Retama*) *retam*, Forsk.—Common throughout Sinai and South Palestine. The juniper ('rothem') of the Bible.

Ononis antiquorum, Linn.—Ain es Sultan, Jericho. An erect shrub, with long stiff spiny branches, bearing scattered sessile flowers, four to six feet high.

**O. campestris*, Koch. (*O. spinosa*, Linn.)—Gaza, prostrate or decumbent on the sands. Perhaps not specifically distinct from the last, but widely so in habit. An addition to the flora of Palestine.

O. natrix, Linn., var. γ *stenophylla*, Boiss.—Gaza; Ramleh to Jerusalem.

O. vaginalis, Vahl.—From Petra to about 4000 feet on Mount Hor. Found hitherto only at Alexandria and in plains under Anti-Lebanon in the Oriental region.

O. serrata, Forsk., var. *major* ?—Bir es Seba to Gaza in several places.

Trigonella arabica, Del.—Jericho.

Medicago denticulata, Willd.—Ghor es Safieh; Wady Ghuweir.

M. laciniata, All.—Between Bir es Seba and Tel Abou Hereireh; Gaza. This minute trefoil was in flower at the end of December.

Hymenocarpus circinnatus, Linn.—Jericho.

Lotus tenuifolius, Rchb., γ *uniflorus*, Boiss. (*L. corniculatus*, var. *L.*)—Swamps in the Ghor es Safieh, near the Dead Sea.

L. lanuginosus, Linn.—Wady el Tihyeh and Jebel Hertih.

L. lamprocarpus, Boiss.—Ghor es Safieh and Jericho.

Hippocrepis unisiliquosa, Linn. var.—Jericho.

Psoralea bituminosa, Linn.—Ghor es Safieh.

P., ? sp., *P. plicata*, Del. ?—Zibb el Baheir and Jebel Watayeh; Jebel Abou Kosheibeh.

Indigofera argentea, Linn.—Ghor es Safieh and El Feifeh. Cultivated, but now spontaneous.

**I. paucifolia*, Del.—Ghor es Safieh. Upper Egypt is its nearest locality in Boissier's Flora Orientalis, but Oliver enumerates it amongst Captain Burton's Indian Plants. An addition to the flora of Palestine.

Tephrosia, ? sp., *T. purpurea*, Pers. ?—Wady el Tihyeh and Jebbel Hertih to Akaba. Apparently this species, but not in good condition. Not mentioned in Boissier's Flora Orientalis.

LEGUMINOSÆ—*continued.*

T. apollinea, Del.—Akaba; Wady Elain.

**Colutea aleppica*, Lam.—Summit of Mount Hor. An addition to the flora of Palestine. Probably this species, but specimens imperfect owing to season.

Astragalus macrocarpus, D. C. ?—A little south of Gaza. Not in fruit.

A. callichrous, Boiss.—Jericho.

A. alexandrinus, Boiss.—Wady Zuweirah to Bir es Seba.

**A. acinaciferus*, Boiss.—On the marl banks by watercourses immediately above the Ghor in the Araba. An addition to the flora of Palestine.

A. sieberi, D. C.—Debbet er Ramleh; Wadies Hamr, Berah, and Lebweh.

A. trigonus, D. C. ?—Wadies Berah and Lebweh.

A. aleppicus, Boiss.—Gaza. Not recorded so far south previously.

A. forskahlii, Boiss.—Wady Araba and Ghor es Safieh.

A. sanctus, Boiss.—Wady Zuweirah to Bir es Seba.

A. sanctus, Boiss., var. *stenophylla* ?—Jericho.

Onobrychus ptolemaica, Del.—Wady Lebweh; Akaba.

Alhagi maurorum, D. C.—Ain Musa; Wadies Elain, es Sheikh, and Ghor es Safieh.

Vicia sativa, Linn., *forma*.—About the Dead Sea.

V. palæstina, Boiss.—With the last.

Lathyrus blepharicarpus, Boiss.—Bethlehem.

Pisum fulvum, S. & S.—Gaza and Bethlehem.

**Rhynchosia minima*, D. C.—Ghor es Safieh, where it covered acacia trees in one or two places by the river with canopies of pretty little flowers. Not included in Boissier's Flora Orientalis, nor found elsewhere so far north of the tropics. "A common tropical plant in both hemispheres," Hooker, Fl. Nigrit. R. schimperi has been lately found in Midian by Burton.

Dolichos lablab, Linn.—Ghor es Safieh in several places, especially along the stream. Widely diffused in warm countries, where it is commonly eaten.

Cassia obovata, Collad.—Akaba. [C. bicapsularis, Linn.—Cultivated at Ain Musa.]

C. acutifolia, Del. (*C. lanceolata*, Forsk.)—Kosseir and Assouan in Upper Egypt are its nearest known localities. An addition to the flora of Sinai.

Ceratonia siliqua, Linn.—First seen at Gaza; frequent northwards. The Caroub, or St. John's locust tree.

Prosopis stephaniana, Willd.—Wady Ghuweir, Ghor es Safieh, Gaza, and Jericho. Very abundant near the Dead Sea, and bearing its monstrous-looking pods in January.

Acacia tortilis, Hayne.—Debbet er Ramleh; Wady Nusb; Akaba; east side of the Araba at El Taba. Frequent in the Ghor where, though only ten or fifteen feet high, it has a thick trunk, and gives considerable shade.

A. seyal, Del.—Frequent in Sinai. Commoner than the last on the west side, in the hotter sandy and arid places. Smaller and more fiercely spiny than A. tortilis, and seldom more than six or seven feet high; usually less, with a flat tabulated top. Leaves more finely pinnated, and bark less red than in the last. Pods different.

A. albida, Del.—Sands at Gaza, close to the Quarantine ground; also, I think, this species at Ain es Sultan, Jericho. Perhaps not native. Inhabits tropical Africa.

**A. lœta*, Br.—Sparingly in the Ghor es Safieh. A handsome tree larger than the other species met with, 20 to 25 feet high. Leaflets considerably larger and fewer, and pod very different from A. tortilis or 'seyal.' An Arab of the Ghor whom I questioned recognized it as distinct, calling it 'sunt,' and pointed out its difference in leaves and pod from the 'seyal.' There have been very confusing statements made about the names, which arise from the Bedouins themselves. A Bedouin at Akaba called a remarkably fine specimen of A. tortilis, by the Egyptian term 'sont.' A lœta has not been found hitherto nearer than Assouan, seven degrees south, and is an important addition to the flora of Palestine.

[N.B.—Many fragments of Medicago etat, not yet in flower. Trefoils had hardly appeared.]

Rosaceæ.

Cratægus sinaica, Boiss.—Near the summit of Jebel Musa.

C., ? sp., *C. Azarolus*, Linn. ?—Near Gaza.

Rubus discolor, W. & N., (*R. sanctus*, Schreb.)—Bethlehem and Jericho.

Poterium verrucosum, Ehr. ?—Wady Ghuweir, Gaza. Not in flower.

P. spinosum, Linn.—Judæa and northwards, common.

Neurada procumbens, Linn.—Wady Lebweh, Gaza.

Lythrarieæ.

Lythrum salicaria, Linn., var. *tomentosum*, D. C.—Twelve to fourteen feet high in the Ghor es Safieh.

L. hyssopifolium, Linn.—Ghor es Safieh and Jericho, in wet places.

[*Lawsonia alba*, Linn.—Hedge-rows near Gaza. Cultivated at Akaba. Not native?]

Cucurbitaceæ.

Cucumis prophetarum, Linn.—Frequent in Sinai to Akaba, and thence to the Dead Sea.

C. trigonus, Roxb.—Ghor es Safieh. Several of this family cultivated in the Ghor.

Citrullus colocynthis, Schr.—Sinai and thence to Ghor; near Bir es Seba.

Bryonia syriaca, Boiss.—Between Ramleh and Jerusalem; A bryony occurred on the summit of Mount Hor; I believe of this species, but it was not in flower.

B. multiflora, Boiss.—Gaza.

FICOIDEÆ.

Aizoon hispanicum, Linn.—Jericho.

A. canariense, Linn.—Ghor es Safieh; Wady Musa.

**Trianthema pentandra*, Linn.—Ghor es Safieh. A native of Senegal, Nubia and tropical Arabia, and found also in Afghanistan and Persia at Bushire. An addition to the flora of Palestine. Has been found in Midian by Captain Burton.

CRASSULACEÆ.

Cotyledon umbilicus, Linn. ?, *Umbilicus intermedius* Boiss. ?—Jebel Watayeh and Zibb el Baheir, west of Mount Sinai. Plentiful on Mount Hor, and on Jebel Abou Kosheibeh. Apparently the same species was common about Bethlehem, but it was nowhere in determinable condition. The root-stock was tuberous. Its leaves did not appear to differ from those of our British species. Recorded by Decaisne under that name.

Sedum, ? sp., *L. altissimum*, Poir. ?—Solomon's Pool, near Bethlehem. Too young to name.

UMBELLIFERÆ.

Eryngium, ? sp.—Wady Ghurundel, east side of Wady Arabah. Too young to determine.

Helosciadium nodiflorum, Linn.—Near Jericho.

Bupleurum linearifolium, D. C.—Jebel Musa; apparently this species also near Bir es Seba.

Deverra tortuosa, Desf.—Frequent in Sinai, extending up the Araba to the Ghor, and across Judæa to Gaza.

Pimpinella cretica, Poir.—Bethlehem.

Torilis nodosa, Gœrt.—Bethlehem.

Chætosciadium trichospermum, Linn.—Bethlehem; Jericho.

Caucalis leptophylla, Linn.—Bethlehem.

Ammi majus, Linn.—Jericho.

Carum, ? sp.—Deir el Arbain, and near the convent on Jebel Catharine.

Ainsworthia trachycarpa. Boiss.

RUBIACEÆ.

**Rubia peregrina*, Linn. ?—Petra and stony slopes of Mount Hor, to Wady Musa. The specimens were barren, but I thought unmistakable. Unfortunately in the hurry of my visit to Petra, I omitted to preserve specimens of this plant. An addition to the flora of Palestine.

R. olivieri, A. Rich.—Ramleh to Jerusalem; Gaza.

Sherardia arvensis, Linn.—Ramleh to Jerusalem.

Galium sinaicum, Dcne.—Wady es Sheikh and Jebel Musa. Confined to Sinai.

G. canum, Req.—Petra and Mount Hor. Not found hitherto so far south.

**Galium petræ*, sp. nov. hispidulum, caulibus diffusis elongatis 4-angulatis fragilibus plus minus intricatis, foliis quaternis angusti linearibus uninerviis rigidiusculis, cymis sæpius paucifloris axillaribus terminalibusque, folio 2-4 plo longioribus pedicellis gracilibus divaricatis hispidulis, fructu (immaturo) pilis brevibus incurvis uncinatisve hispido.* Hab. in Wady Musâ, apud Petram. Foliis 1½–2 lineæ longis setiformibus, internodis inferioribus 7-8 lineæ longis, verticillatis foliorum supremis approximatis. "Affinis G. jungermannioides sed foliis quaternis nec senis, caule ramisque elongatis nec pulvinatis, ..." E. Boissier in litteris ad mihi. [Plate XVI., fig. 1.]

G. aparine, Linn.—Jericho and Gaza.

G. judaicum, Dcne.—Bethlehem. Confined to Palestine, from Lebanon to Jerusalem.

DIPSACEÆ.

**Pterocephalus sanctus*, Dcne.—Jebel Musa; Deir el Arbain and Jebel Catharine, Petra and Mount Hor. An addition to the flora of Palestine. Hitherto found only on Sinai.

COMPOSITÆ.

Bellis sylvestris, Cyr.—Rocky places about Bab el Wad, between Ramleh and Jerusalem.

Asteriscus pygmæus, Coss.—Abundant on the Edomite escarpment, at the head of Wady Ghurundel; Ghor es Safieh.

A. graveolens, Forsk.—Frequent on Sinai.

Anvillæa garcini, D. C.—Wady Haroun.

Inula crithmoides, Linn.—Ghor es Safieh, 4 to 7 feet high.

I. viscosa, Desf.—Wadies east of the Araba; Ghor es Safieh; between Ramleh and Jerusalem.

I. dysenterica, Linn.—Ghor es Safieh.

Pulicaria arabica, Cass.—Ghor es Safieh; Ain Abou Weirideh in the Arabah.

P. (*Francoeuria*) *crispa*, Forsk.—Jebel Musa, Wady Elain, Ghor es Safieh.

P. undulata, D. C.—Throughout Sinai to the Dead Sea.

Iphiona juniperifolia Cass.—Frequent at about the near elevation of Sinai, as at Wady es Sheikh, &c.

I. scabra, D. C.—Wadies Zelegah and Elain.

**Varthamia montana*, Vahl.—Wadies Lebweh, Berah and es Sheikh; Mount Hor. An addition to the flora of Palestine. Known previously to my visit from Sinai only.

Pluchea dioscorides, D. C.—Wady Ghuweir, Ghor es Safieh. A bushy composite, 12 to 15 feet high, in Wady Ghuweir.

**Erigeron* (*Conyza*) *bovei*, D. C.—Wady Elain and Ghor es Safieh. Attaining the height of 10 feet in Wady Elain amongst tamerisk bushes. An addition to the flora of Palestine.

Phagnalon nitidum, Fres.—Wadies Lebweh and es Sheikh.

Leyssera capillifolia, Willd.—Frequent on Sinai and along the Arabah to the Dead Sea.

Evax contracta, Boiss —Jericho.

* This description has been kindly furnished me by Professor Oliver.

COMPOSITÆ—*continued.*

Evax anatolica, Boiss.—Jebel Usdum.

Filago prostrata, Parlat.—Wady Hessih, south-west of Akaba.

Iflago spicata, Forsk.—Along the Tih escarpment, in many places between Sinai and Akaba; Wady Haroun.

**Eclipta alba*, Linn.—Ghor es Safieh. An addition to the flora of Palestine. A tropical and sub-tropical species found in Egypt.

Xanthium strumarium, Linn. ?—Gaza.

Achillea santolina, Linn.—Wady Zuweirah to Bir es Seba.

Anthemis, ? sp.—Unrecognizable young plants of this genus, and the last, occurred at Jericho and elsewhere.

Matricaria aurea, Boiss.—Jericho,

M. auriculatum, Boiss.—Ghor es Safieh.

Chrysanthemum coronarium, Linn.—Jericho.

Pyrethrum santalinoides, D. C.—Wady es Sheikh; Jebel Musa.

Cotula cinerea, Del.—Wady Ghurmedel ("Elim.")

Artemisia monosperma, Del.—Abundant at Akaba; Ain Abou Weiridh in the Arabah; Gaza.

A. herba-alba, Asso., var. *laxiflora*.—Wady es Sheikh.

A. herba-alba, Asso.—Abundant with several varieties from Wady Lebweh to Wadies Zelegah and Elain, and occurs between Bir es Seba and Tel Abou Hererieh. At Wady Elain a variety, with densely aggregated reddening flower-heads, occurs.

A. judaica, Linn.—Wady Sudr. Several indeterminable Artemisiæ were gathered.

Santolina fragrantissima, Forsk.—Abundant at a moderate elevation in Sinai, but very scarce after Akaba.

Senecio vernalis, W. K.—Gaza and Jericho.

S. coronopifolius, Desf.—Ghor es Safieh, and across Judæa to Gaza.

Calendula arvensis, Linn.—Wady Zuweirah to Gaza.

**Tripteris vaillantii*, Dcne.—Petra and lower slopes of Mount Hor. An addition to the flora of Palestine.

**Echinops glaberrimus*, D. C.—Wadies Lebweh, es Sheikh, and Haroun; Zibb el Baheir. Wady Haroun brings the range within Canon Tristram's limits allotted to Palestine, to which flora it is an addition. Hitherto believed peculiar to Sinai.

Carduus argentatus, Linn.—Bethlehem.

Atractylis flava, Desf.—Wady Hessih, a little south of the Hadj road, near Akaba; at Ain Musa.

A. prolifera, Boiss.—Gaza.

Amberboa lippii, D. C.—Jericho; noted from the Tih desert, but not from Palestine Proper previously.

A. crupinoides, Desf.—Ghor es Safieh; Jericho.

Centaurea sinaica, D. C.—Wady Hessih; apparently this species, but withered.

C. araneosa, Boiss.—Gaza; Medjel to Jaffa.

Centaurea iberica, Trev.—Ghor es Safieh.
C. pallescens, Del.—Gaza.
C. eryngoides, Lam.—Zibb el Baheir; Jebel Musa; Mount Hor.
C. (*Phœopappus*) *scoparia*, Sieb.—Wadies Lebweh and es Sheikh; Jebel Musa.
Carthamus lanatus, Linn.—Wady Haroun.
C. glaucus, M. B.—Wady Araba; Bir es Seba to Tel Abou Hereireh.
Cichorium intybus, Linn.—Jericho. In flower in the middle of January.
Hedypnois cretica, Linn.—Jericho.
Tolpis altissima, Pers.—Gaza and Tel Abou Hereireh.
Thrincia tuberosa, Linn.—With the last. At a little distance closely resembles our dandelion.
Hagioseris, ? sp. *H. galilæa*, Boiss. ?—Jericho. *Picris*, ? sp.—Jericho.
Urospermum picroides, Linn.—Bethlehem.
**Scorzonera alexandrina*, Boiss.—Tel Abou Hereireh to Gaza. Specimens determined by Mons. Boissier. Hitherto found only at Tunis, Algiers, and Alexandria. An addition to the flora of Palestine.
S. lanata, M. B.—With the last species, and about Bir es Seba.
**Sonchus maritimus*, Linn.—Sparingly near the Dead Sea in the Ghor as Safieh. An addition to the flora of Palestine.
Zollikoferia, ? sp., *Z. casinianæ*, Jaub. ?—Apparently this species, from Mount Hor and Ghor es Safieh. Recorded from Egypt and the shores of the Red Sea at Kossni. An addititon (if correct) to the flora of Palestine.
Z. stenocephala, Boiss., vel. *Z. arabica*, Boiss.—Specimens incomplete. Wady Zuweirah. The first-mentioned form has been only collected at Beloochistan.
Z. nudicaulis, Linn.—Akaba; Wady Elain; Ghor es Safieh.
Z. spinosa, Forsk.—Wadies Nusb and Lebweh; Akaba.
**Crepis senecioides*, Del.—Bethlehem, near Solomon's Pool. The localities known to Boissier are Alexandria, Cairo and Sackara, in Egypt. An addition to the flora of Palestine.

Ericaceæ.

Arbutus andrachne, Linn.—Limestone cliffs above Bab el Wad, between Ramleh and Jerusalem.

Primulaceæ.

Anagallis arvensis, Linn.—Jericho.
A. arvensis, Linn. var. *cærulea*.—Jericho; Bethlehem.
A. latifolia, Linn., = var. *A. arvensis* ?.—Ghor es Safieh.
Lysimachia dubia, Ait.—Ghor es Safieh, near the Dead Sea.
Cyclamen latifolium, Sibth.—First seen near Bir es Seba; thence to Jerusalem. Common.
Primula boveana, Dcne.—Wady es Sheikh. Not in flower.

OLEACEÆ.

Olea europea, Linn.—Olive trees were measured a little north of Gaza, having a circumference of 18 and 20 feet a couple of feet above the ground. These were the largest and oldest trees seen. Schweinfurth has suggested that this tree, perhaps the oldest cultivated, was originally derived from the Nubian mountains, where he has found it native.

SALVADORACEÆ.

Salvadora persica, Garcin.—Ghor el Feifeh and es Safieh. Very abundant, forming dense groves, and giving off a heavy smell, resembling that of a monkey-house. Found also in Sinai. See *ante*, p. 405.

APOCYNEÆ.

Nerium oleander, Linn.—Wadies Musa, Haroun, Ghuweir, and Ghurundel, in Edom; and in the wadies of Moab leading to the Ghor el Feifeh and es Safieh; Jericho.

ASCLEPIADEÆ.

Calotropis procera, Willd.—Ghor el Feifeh and Safieh. Found also in Sinai.

**Pentatropus spiralis*, Forsk.—Not in flower, but Mr. Oliver believes this species. Ghor es Safieh and Wady Haroun. Mascat, in South-east Arabia, is the only habitat in the region in Boissier's Flora Orientalis. A native of tropical countries and an addition to the flora of Palestine.

Dæmia cordaba, Br.—Frequent in Sinai and along the Arabah to the Dead Sea. In most of the Edomitic wadies and about Akaba, as also in the wadies on the west side of the Arabah. In Wady Haroun climbing to ten or twelve feet in height on Ochradenus.

Gomphocarpus sinaicus, Boiss.—Wadies Lebweh and es Sheikh; Ain abou Zuweirah and Mount Sinai, near the convent; Akaba; Jebel Abou Kosheibeh. In cultivation in a garden at Jaffa.

Cynanchum acutum, Linn.—Climbing over reeds at Ain Abou Weiredeh in Wady Arabah; Wady Ghuweir; Ghor es Safieh; by the Jordan, at the pilgrims' bathing-place. Only mentioned from the maritime districts of Palestine by Tristram.

Leptadenia pyrotechnica, Forsk.—Ghor el Fefieh and es Safieh sparingly; by the Dead Sea, at the northern end of Jebel Usdum.

**Boucerosia aaronis*, sp. nov.—Herba succulenta, 4–6 pollicaris, ramis erectis parce ramosis rigidis 4-gonis angulis acutis remote tuberculato dentatis, floribus livido-purpureis, corolla notata, limbo profunde 5-fido lobis ovato-deltoideis intus glabris vel obsolete puberulis, coronæ staminæ lobis interioribus oblongis obtusissimis incumbentibus, exterioribus bifidis dentibus divaricatis, lobis interioribus paullo brevioribus. Fl. Dec.

Hab.—In aridis saxosis locis, Montium Aaronis et "Abu Kosheibeh".

Tota planta fere pallida-fusca, carnosæ, aphylla, facie *Stapeliâe* (Descriptiones specierum Boucerosiæ in Flora Orientale minime sufficientes sunt). Hæc species ab eis videtur distincta. [Plate XVII., figs. 1 to 8.]

GENTIANACEÆ.

**Erythræa spicata*, Pers.—Ghor es Safieh. An addition to the flora of Palestine.

CONVOLVULACEÆ.

Convolvulus lanatus, Vahl.—Wady Nusb.

C. siculus, Linn.—Jericho to Marsaba.

C. arvensis, Linn.—Gaza and Jericho. Several other indeterminable convolvuli from Sinai and Gaza.

Cressa cretica, Linn.—Ain Musa; Wady Ghurundel (Elim); Akaba; Ain Abou Weirideh in the Araba; Ghor es Safieh.

Cuscuta, sp., ? *C. palæstina*, Boiss.—On mint at Jericho.

BORAGINEÆ.

Heliotropium luteum, Poir.—Wady Ghurundel (Elim), and other wadies between that and Mount Sinai.

H. rotundifolium, Boiss.—Wadys Haroun and Zuweirah; about Bir es Seba.

H. arbainense, Fres.—From Akabah to the Ghor es Safieh in many places.

H. undulatum, Vahl.—Wady Lebweh; Wady El Tihyeh to Jebel Hirteh; Akaba.

Anchusa aggregata, Lehm.—Gaza.

A. ægyptiaca, Linn.—Bethlehem and Gaza.

A. milleri, Willd.—Wady Zuweirah to Bir es Seba; Jericho and Gaza.

Podonosma syriacum, Lab.—Jebel Abou Kosheibeh and Mount Hor (the specimens from here were withered); Jerusalem; Bethlehem.

Onosma (? sp.), ? *O. giganteum*, Linn.—Apparently this species, but withered, on Mount Hor.

Echium plantagineum, Linn.—Wady Zuweirah to Gaza; Jaffa.

Arnebia cornuta, Ledeb.—Jericho.

A. linearifolia, D. C.—Wady Zuweirah to Bir es Seba.

Lithospermum tenuiflorum, Linn.—Wady Zuweirah to Bir es Seba; Jericho.

L. callosum, Vahl.—Gaza; Wady Ghurundel (Elim).

Alkanna tinctoria, Linn.—Ramleh to Jerusalem, in several places.

A. orientalis, Linn.—Jebel Musa; Mount Hor and Jebel Abou Kosheibeh; Wady Es Sheikh; Jerusalem.

Asperugo procumbens, Linn.—Jericho.

Trichodesma africanum, R. Br.—Wadys Lebweh and Es Sheikh; Akaba to Wady Haroun Ghor es Safieh.

SOLANACEÆ.

Solanum nigrum, Linn.—Gaza and Ghor es Safieh. Var. *moschatum*, in Wady Ghurundel (Edom). Very variable.

SOLANACEÆ—*continued.*

Solanum coagulans, Forsk., *S. sanctum*, Linn.—Ghor el Feifeh and es Safieh.

Withania somnifera, Linn.—Tel Abou Hereireh, near Gaza.

Lycium europæum, Linn.—Debbet er Ramleh and Wady Haroun, abundant; Akaba: between Tel Abou Hereireh and Bir es Seba.

L. arabicum, Schwf.—Wadies Elain and Haroun.

Mandragora officinarum. Linn.—Tel Abou Hereireh to Gaza; Jericho; near the Ghor.

Datura stramonium, Linn.—Apparently this species, but not perfect, at Gaza.

Hyoscyamus muticus, Linn.—Wadies Sudr and Elain: Wady Ghuweir—the "sekkaran" of the Arabs.

H. aureus, Linn.—Wady Elain; Mount Hor; Tel Abou Hereireh to Gaza; Jericho and Jerusalem.

SCROPHULARIACEÆ.

Verbascum sinaiticum D. C.—Jebel Musa; Wadies Zelegah and Elain; Mount Hor.

V. sinuatum, Linn.—Akaba; Jebel Hertih and Wady Hessih; Wady Araba and Ghor es Safieh.

**Celsia parviflora*, Dcne.—Jebel Musa; Ghor es Safieh. Only known from Jebel Catharine in Sinai. An addition to the flora of Palestine.

Anarrhinum pubescens, Fres.—Deir el Arbain at Jebel Catharine; Wadies Lebweh and Es Sheikh. Confined to Sinai so far as known.

Linaria floribunda, Boiss.—Wady el Tihyeh to Jebel Hertih, south-west of Akabah. Not previously found in Sinai.

L. elatine, Linn.—Ghor es Safieh.

**L. macilenta*, Dcne.—Wady Elain; Akaba; Wady Haroun. The last locality makes this rare species an addition to the flora of Palestine.

L. hoelava, Forsk., sub. *Antirrhino*.—Jericho and Gaza.

L. micrantha, Cavan.—Jericho. Noted in "Northern Plains" in Palestine.

L. albifrons, S. & Sm. Jericho.

Antirrhinum orontium, Linn.—Ghor es Safieh; Jericho.

**Scrophularia heterophylla*, Willd., *forma*.—Wady Musa, Petra and Mount Hor. Appears to be known only from Greece and its confines. An addition to the flora of Palestine.

S. xanthoglossa, Boiss.—Sands at Gaza.

S. deserti, Del.—Wady Elain; El Taba, Wady Arabah.

S. variegata, M. B. ?—Jericho.

S. canina, Linn. ?—Gaza. And other indeterminable Scrophulariæ from Petra and elsewhere.

**Lindenbergia sinaica*, Dcne.—Wady el Tihyeh to Jebel Hertih; Wady Ghuweir; Ghor es Safieh. An addition to the flora of Palestine.

Veronica anagallis, Linn.—Jerusalem, Jericho and Bethlehem.
V. beccabunga, Linn.—Jerusalem.
V. syriaca, R. & S.—Jericho; Deis el Arbain at Jebel Catharine, in the monastery enclosure.

OROBANCHACEÆ.

Orobanche (*Phelipæa*) *ægyptica*, Pers.—On Cucurbitaceæ, near Ain es Sultan, at Jericho. A very showy blue species, with the base of the corolla yellow. In flower in January.
O. cernua, Loefl.—Ghor es Safieh.

ACANTHACEÆ.

Blepharis edulis, Forsk, *Acanthodium spicatum*, Del.—Wadies Lebweh and Es Sheikh; Ghor es Safieh.

GLOBULARIEÆ.

Globularia alypum, Linn., var., *G. arabica*, J. & Sp.—Jebel Abou Kosheibeh.

VERBENACEÆ.

Lantana camera, Linn.—Cultivated at Ain Musa.
Verbena officinalis, Linn.—Ghor es Safieh.
Vitex agnus-castus, Linn.—Between Jericho and the Jordan.

LABIATÆ.

Lavandula stæchas, Linn.—Medjel to Jaffa.
L. coronopifolia, Poir.—Wady Nusb to Akaba, frequent; wadies about Mount Hor.
Mentha sylvestris, Linn., *β stenostachya*, Boiss.—Ghor es Safieh; Jericho.
,, ,, *γ lavandulacea*, Boiss. — Jebel Musa; Deir el Arbain at Jebel Catharine.
Lycopus europæus, Linn.—Ghor es Safieh. Recorded from North Palestine.
Origanum maru, Linn., *β sinaicum*, Boiss.—Jebel Musa; Mount Hor.
,, ,, ? *forma*.—Bethlehem.
Thymus capitatus, Linn.—Between Medjel and Jaffa; Solomon's Pools.
Satureia cuneifolia, Ten. ?—Bir es Seba to Tel Abou Hereireh.
,, ,, *forma*.—Wady Ghurundel (Edom).
Micromeria nervosa, Desf.—Between Bab el Wad and Jerusalem.
**M. sinaica*, Bth.—Jebel Catharine. Rocky ledges above the Tufileh river, near the Ghor. An addition to the flora of Palestine.
M. juliana, Linn., *β myrtifolia*, Boiss.—Above Bab el Wad, between Ramleh and Jerusalem.
M. serpyllifolia, M. B., *β barbata*, Boiss.—Between Ramleh and Jerusalem.
Salvia triloba, Linn.—Bab el Wad, between Ramleh and Jerusalem.

LABIATÆ—*continued.*

Salvia verbenacea, Linn.—Frequent on the Judæan plain, from Wady Zuweirah to Gaza.
S. controversa, Ten.—Bir es Seba to Gaza.
S. viridis, Linn.—Jericho.
S. ægyptiaca, Linn.—Wady Haroun; Ghor es Safieh, and thence to Gaza.
**S. deserti*. Dcne.—Akaba; Wady Haroun. An addition to the flora of Palestine.
Nepeta septemcrenata, Ehr.—Jebel Musa; Wady es Sheikh.
Marrubium alysson, Linn. ?—Specimens imperfect. Bir es Seba.
Stachys affinis, Fres.—Wadies Lebweh, Berah and Es Sheikh; frequent.
Lamium amplexicaule, Linn.—Gaza; Jericho; Bir es Seba.
Ballota undulata, Fres.—Wadies Lebweh, Es Sheikh and Ghurundel (Edom). Bir es Seba to Tel Abou Hereireh.
B. schimperi, D. C.—Wady Elain.
**Phlomis aurea*, Dcne.—Jebel Musa; Mount Hor. An addition to the flora of Palestine.
Eremostachys laciniata, Linn.—Bir es Seba to Tel Abou Hereireh.
Prasium majus, Linn.—Gaza.
Ajuga iva, Schreb.—Gaza; Wady Zuweirah to Bir es Seba; Jericho.
A. chia, Poir., δ *tridactylites*.—Jebel Catharine and Mount Hor.
Teucrium polium, Linn.—Zibb el Baheir; Wadies Lebweh, Es Sheikh and Elain; Jebel Musa and Jebel Catharine. A common labiate from about 2500 feet upwards.
**T. sinaicum*, Boiss.—Wady Elain; Mount Hor and Petra. An addition to the flora of Palestine.

PLUMBAGINEÆ.

Statice thouini, Viv.—Jericho.
S. pruinosa, Linn.—Ain Abou Weirideh in the Arabah.

PLANTAGINEÆ.

Plantago albicans, Linn.—Wady Sudr in Sinai; Gaza.
**P. loeflingii*, Linn.—Jebel Usdum; Jericho. An addition to the flora of Palestine.
P. ovata, Forsk.—Wady Hessih in Sinai; Ghor es Safieh.
P. lagopus, Linn.—Bethlehem; Jericho.
P. arabica, Boiss.—Jebel Musa.
P. arenaria, W. K.—Jericho.

CYNOCRAMBEÆ.

Cynocrambe prostrata, Gært., *Thelygonum cynocrambe*, Linn.—Between Ramleh and Jerusalem.

SALSOLACEÆ.

Chenopodium album, Linn.—Jericho.

C. murale, Linn.—Gaza; Jericho; Ghor es Safieh.

Atriplex hastatum, Linn.—Ghor es Safieh.

A. tataricum, Linn., ? *forma*.—Ghor es Safieh.

A. patulum, Linn.—Ghor es Safieh.

**A. alexandrina*, Boiss.—Jebel Usdum; Jericho. Hitherto found only in Tunis and Alexandria. An addition to the flora of Palestine.

A. crystallinum, Ehr.—Akaba. A scarce Egyptian species, not found elsewhere previously.

**A. leucocladum*, Boiss.—Wadies Ghurundel (Elim), Es Sheikh, Elain, &c.; Akaba; Ghor es Safieh; Eltaba in the Arabah. An addition to the flora of Palestine.

A. halimus, Linn.—Wady Elain; Ghor es Safieh.

Salicornia fruticosa, Linn.—Gaza.

S. herbacea, Linn.—Ghor es Safieh.

Suæda monoica, Forsk.—Wady es Sheikh, Akabah; Eltaba in the Arabah; Ghor es Safieh. Dries black.

S. asphaltica, Boiss.—Ain Abou Weirideh in the Arabah.

S. fruticosa, Linn., *β brevifolia*.—Ghor es Safieh; Jericho.

Traganum nudatum, Del.—Wady Ghurundel, on the east side of the Arabah.

**Salsola inermis*, Forsk.—Jebel Usdum; Petra; Gaza. This species has been found only near Alexandria, in Forskahl's old locality. An addition to the flora of Palestine.

S. tetragona, Del.—Ghor es Safieh and Jebel Usdum; Wady Ghuweir in Edom.

**S. longifolia*, Forsk.—Jebel Usdum. Known only from Egypt, where Forskahl originally discovered it. An addition to the flora of Palestine.

**S. fœtida*, Del.—Jebel Usdum; Eltaba in the Arabah. An addition to the flora of Palestine.

S. rigida, Pall.—Mount Hor.

,, var. *tenuifolia*, Boiss.—Jebel Usdum.

Noæa spinosissima, Moq.—Tel Abou Hereireh to Gaza; Jebel Usdum; Mount Hor, summit.

Anabasis aphylla, Linn. ?—Wady Lebweh. Named doubtfully.

A. articulata, Forsk.—The commonest plant throughout Sinai to the Dead Sea. Less frequent from the Ghor to Gaza.

**A. setifera*, Moq.—Ain Musa; Wadies Ghurundel (Elim), Es Sheikh and Elain; Jebel Usdum; Tel Abou Hereireh to Gaza. An addition to the flora of Palestine.

N.B.—The species of the above order have been almost entirely determined by M. Boissier.

AMARANTACEÆ.

Albersia blitum, Kunth.—Ghor es Safieh: at a well in Wady Nusb. Not native (?).

A. caudatus, Linn.—Ghor es Safieh. Appeared amongst seeds brought from there, and grown by Mr. Burbidge.

AMARANTACEÆ—*continued.*

Œrua javanica, Juss.—Frequent in Sinai, from Wady Sudr to Akaba; Ghor es Safieh. Var. *β bovei*, Welb., was also gathered, as in Wady Lebweh.

**Digera arvensis*, Forsk.—Ghor es Safieh and Ghor el Feifeh. D. alternifolia, Linn., an erect annual, is the only species in Boissier. The plant of the Ghor is the decumbent perennial given in Forskahl's "Flora Egyptiaco-Arabico," at p. 65. An addition to the flora of Palestine.

POLYGONEÆ.

Calligonum comosum, Her.—Above Akaba, westward from the Hadj-road to Jebel Hertih. Ain Abou Weirideh to the Ghor, and elsewhere in the Arabah.

Emex spinosus, Linn.—Gaza and Jericho.

Rumex roseus, Linn.—Jericho; Ghor es Safieh and Petra.

R. vesicarius, Linn. ?—Ghor es Safieh. These two species are (if distinct) sometimes confounded.

R. obtusifolius, Linn.—Gaza.

Polygonum equisetiforme, S. & S.—Frequent on the Edomitic side of the Araba, from Petra northwards; Ghor es Safieh, and between Bir es Seba and Gaza.

NYCTAGINEÆ.

Boerhaavia plumbaginea, Cav., *forma*, var. (?) *incisa*.—Akaba.

**B. verticillata*, Poir.—Wady Haroun and Ghor es Safieh; between Gaza and Tel Abou Hereireh. Fragments from Wadies Ghurundel and Ghuweir appear to belong to this species, which is recorded only from Mascat in south-east Arabia, in the Oriental region, by Boissier. It occurs, however, in Nubia, Senegal and Abyssinia, according to Hooker's "Flora Nigritiana," which is a not unfrequent range for the desert plants. An addition to the flora of Palestine.

**B. repens*, Linn.—Ghor es Safieh and Jericho. An Egyptian species found in tropical Arabia, and from Morocco to India. An addition to the flora of Palestine.

THYMELÆACEÆ.

**Daphne linearifolia*, sp. nov.—Fruticosa ramosa, ramulis tenuibus rubellis, glabris foliosis, foliis linearibus acuminatis utrisque uninerviis glabris sessilibus, floribus 10–15 brevissime pedicellatis capitatis terminalibus sessilibus, pedicellis scabridulo hispidis, perigoniis dense et breviter villosis pallido-flavis, lobis lanceolatis mucronatis, tubo 2–3 plo brevioribus, bacca rubra-fusca,

Frutex 4–6 pedalis. Folia 1½–2 pollicaris, 1 linea lata. Perigonium sub anthese 2 lineas longum.

Hab. Petra et ad basim Montis Aaronis prope Petram, circa 2800–3400 pedes supra Mare Mediterraneum.

Affinis D. acuminata, Boiss., "Flor. Orient," vol. iv., p. 104–8, et D. mucronata, Royle, Ind. III., p. 322, tab. 81, sed distinguenda præsertim a foliis linearibus fere gramincis, et a floribus minutis pallidis-flavis. [Plate XVI., fig. 2.]

Thymelæa hirsuta, Linn.—Mount Hor and Petra; Bir es Seba.

T. ? sp.—Tel Abou Hereireh.

Loranthaceæ.

Viscum cruciatum, Sieb.—Near Jerusalem. Very like our mistletoe, except in the berries, which are red.

Loranthus acaciæ, Zucc.—Abundant on acacias and nubk (Zizyphus), in a grove several miles in length on the east side of the Araba, about fifteen miles north of Akaba. In Wady Ghuweir, on tamarisk and nubk; plentiful in Ghor el Feifeh and Ghor es Safieh and near Jericho, on nubk. This species may be dependent on the visits of the sun-bird for the fertilization of its flowers. Specimens of this bird (Cinnyris oseæ) were obtained with their long bills covered with the pollen of the tubular flowers which the bill is well fitted to probe. I may add that they usually occur together, as at Jericho, Ghor es Safieh, and near Eltaba. The berries are red, cup-shaped and soft, with a single large hard seed.

Euphorbiaceæ.

**Euphorbia ægyptiaca*, Boiss.—Ghor es Safieh. A tropical African species, ranging from Egypt, Nubia and Abyssinia, to the Cape de Verdes, and Senegal on the west, and northern India on the east. An addition to the flora of Palestine.

E. cornuta, Pers.—Frequent in Sinai, especially on the western side.

E. helioscopia, Linn.—Jericho; Gaza to Jaffa.

E. exigua, Linn.—Apparently this species; but, although flowering, the plants were not an inch in height, and very difficult to detect. They were probably seedlings. At Tel Abou Hereireh and Gaza.

E. aulacosperma, Boiss.—Bethlehem.

E. peplus, Linn.—Jericho.

E. peploides, Gou.—Gaza.

E. chamæpeplus, Boiss., *β sinaica*, Boiss.—Jericho.

E. terracina, Linn.—Gaza.

E. paralias, Linn.—Gaza.

Andrachne aspera, Spreng.—Frequent in Sinai from Wady Lebweh to Akaba, and along the Arabah to the Ghor; Gaza.

Crozophora obliqua, Vahl.—Wadies Nusb, Es Sheikh, and Ghor es Safieh.

EUPHORBIACEÆ—*continued.*

Mercurialis annua, Linn.—Gaza; Jaffa; Jericho and Ghor es Safieh.
Ricinus communis, Linn.—Ghor es Safieh; near Gaza, a little southwards.

URTICACEÆ.

Urtica dioica, Linn.—Jericho.
U. urens, Linn., and *U. pilulifera*, Linn.—Both were gathered, I believe, at Gaza; but they were not in flower.
Parietaria (? sp.), ? *P. judaica*, Linn.—Jerusalem, &c.
Forskahlia tenacissima, Linn.—Frequent in Sinai. Plentiful at Akaba, and up the Arabah to the Ghor.
Ficus carica, Linn.—Wady Ghuweir, a valley leading from north-eastern Arabah to the Shobek country in Edom.
F. sycamorus, Linn.—Gaza; Wady Ghurundel (Edom).

CUPULIFERÆ.

Quercus coccifera, Linn.—Bab el Wad to Jerusalem, &c.
**Salix acmophylla*, Boiss. (?).—Wady Ghuweir; Ghor es Safieh, by the Tufileh river. In the absence of inflorescence, Mr. Oliver would not name the species positively. There seems, however, to be very little doubt about it. An addition (in all probability) to the flora of Palestine.
Populus euphratica, Oliv.—Ain Abou Weirideh in the Arabah; Ghor es Safieh and El Feifeh; by the Jordan below Jericho. Leaves of various shapes, from linear or linear lanceolate to broadly ovate, rhomboid, sinuate, inciso-dentate, lobed, or quite entire. A single mature tree near the Dead Sea is of considerable size, with uniform foliage. A bush of this species, I believe (saf-saf), occurs near the spring on Jebel Musa; but I unfortunately omitted to bring home a specimen. According to the Arabs, who say it makes the best charcoal for gunpowder, it occurs in the valley between Jebel Musa and Jebel Catharine, but is nearly all gone.

ARACEÆ.

Arum (? sp.), ? *A. dioscoridis*, Sibth.—Gaza.
Arum (? sp.)—Summit of Mount Hor.
Arisarum vulgare, Targ.—Common about Gaza.

PALMÆ.

Hyphæne thebaica, Del.—Akaba. Found also in Sinai at Tor. Akaba is the northernmost limit of the range of this palm. No doubt, in former times, it ranged through Sinai

more abundantly, and perhaps to the Dead Sea. It would be interesting to submit some sections of the sub-fossil palms, found at Callirhoe and elsewhere in the Ghor, to microscopical examination. Captain Burton found the palm very frequent in Midian. Its headquarters are in tropical Africa.

Phœnix dactylifera, Linn.—Frequent in Sinai and up the Araba, nearly to the Dead Sea, but not occurring in the Ghor es Safieh ; Wady Ghuweir. A single well-grown tree at Riha or modern Jericho, in the plain of the Jordan, seems to have escaped the observation of travellers. A solitary tree in the convent at Mar Soba is said to bear a stoneless date. The date-palms of Sinai are usually very poor specimens.

TYPHACEÆ.

**Typha angustata*, B. & C.—Wady Ghurundel (Elim) ; Wady Elain in two places. I feel sure I saw it in the Ghor, but omitted to preserve specimens. An addition to the flora of Palestine.

IRIDACEÆ.

Iris (*Xiphion*) *palæstinum*, Baker.—Tel Abou Hereireh to Gaza ; Gaza to Jaffa, &c., common. Coming into flower the last week in December. Flowers sweet-smelling.

AMARYLLIDACEÆ.

Sternbergia macrantha, Gay.—Mount Hor, especially about the summit. In flower early in December. A large showy yellow species.

Narcissus tazettæ, Linn.—Between Medjel and Jaffa. Coming into flower in the first week of January.

Pancratium sickenbergeri, A. & S.—Debbek er Ramleh ; Wadies Lebweh and Es Sheikh ; in several places in the Araba, from Akaba to Ain Abou Weirideh. Flowering November and December, but without leaves. A beautiful white-flowered species found elsewhere only in the neighbouring Egyptian deserts.

COLCHICACEÆ.

Colchicum montanum, Linn.—Abundant on the plain of Judæa, from the Ghor to Gaza ; near the summit of Mount Hor. In flower the second week of December. Flowers white or mauve.

C. steveni, Kunth.—I gathered flowers, which Mr. Oliver refers to this species, on the summit of Jebel Catharine, 8500-8600 feet, on the 19th November ; summit of Mount Hor, in flower, 10th December. Boissier gives maritime plains of Palestine, Cilicia, and Mersina for its known geographical range. Flowers white or faintly lilac, and appearing without leaves on Jebel Catharine, one, two or three to the scape. On Mount Hor the flowers were decidedly smaller, and sprang from a leafy shoot. The latter is normally the case in this species ; and possibly the Jebel Catharine plant is distinct, and belongs to the section of the genus in which the flowers are autumnal, the leaves vernal.

COLCHICACEÆ—*continued.*

Androcymbium (*Erythrostictus*) *palæstinum*, Boiss.—Wady Arabah, and wadies leading into it near the Ghor; Gaza; from near Jerusalem to Jericho; Ghor es Safieh. In flower 13th December, and afterwards.

LILIACEÆ.

Gagea reticulata, Pall.—Gaza; Bethlehem; Jericho; Jerusalem. In flower 4th January.

Uropetalum erythræum, Webb (?).—Sinai and in the Araba, frequent; withered, but I think this species.

Ornithogalum umbellatum, Linn.—Tel Abou Hereireh to Gaza, and at Gaza. Gaza to Jerusalem frequently.

Urginea scilla, Sternh.—Abundant in Judæa. Apparently this species throughout Mount Hor and the Edomitic escarpment, at a moderate elevation, from the Ghor es Safieh to Wady Ghurundel, but only in leaf.

**U. undulata*, Desf.—This plant flowered since my return under Mr. Burbidge's care, and Mr. Baker refers it to the present species. These bulbs were greedily sought after by wild boars. I found them sparingly in the Wady Arabah near the Ghor, and again at Bir es Seba, generally only broken remains. An addition to the flora of Palestine.

Muscari racemosum, Linn.—Jerusalem to Jericho; in flower in the second week of January.

Bellevallia flexuosa, Boiss.—Wadies Ghuweir, Haroun, Musa and Abou Kosheibeh; Tel Abou Hereireh; Ghor es Safieh; Bethlehem, &c. A white variety occurs near Bethlehem. Slightly sweet-scented. In flower first week of December.

Asphodelus fistulosus, Linn.—Wadies Lebweh and Ghuweir; Ghor es Safieh; Gaza and Jericho. In flower in the middle of December.

A. ramosus, Linn.—Abundant in the Judæan plain, from Bir es Seba to Gaza; about the Ghor es Safieh, from a few hundred feet above the level of the Dead Sea upwards, In some places nearly as abundant as the squill. In flower the first week of January.

Allium sinaiticum, Boiss.—Wady Haroun and Mount Hor, "a very rare species, with the alternate filaments bearing three distinct cusps as in A. ponum and A. sativum." Flowered in the Trinity College Botanic Gardens, Dublin, since my return. Determined by Mr. Baker.

N.B.—Bulbous plants of many other species in the four foregoing orders were brought home, and are almost all growing. Only in a few instances have they, however, thrown out flowers.

ASPARAGACEÆ.

Asparagus aphyllus, Linn.—Jebel Abou Kosheibel; Gaza; Ramleh to Jerusalem. Recorded from Nazareth only.

A. acutifolius, Linn.—Mount Hor; Medjel to Jaffa. Recorded only from Lower Lebanon.

JUNCACEÆ.

Juncus subulatus, Forsk., *J. multiflorus*, Desf.—Ghor es Safieh.

J. acutus, Linn.—Gaza; a stunted form.

J. maritimus, Lam., *β arabicus*, A. B.—Wadies Sudr, Ghurundel (Elim), and Elain. Akaba; in the Arabah and Ghor es Safieh. The common form was seen also at Gaza and Ghor es Safieh. The desert form acquires the whitened appearance characteristic of its flora, and is very large.

CYPERACEÆ.

**Cyperus lævigatus*, Linn.—Wady Elain; Gaza. An addition to the flora of Palestine.

C. distachyos, All.; *C. lævigatus*, var. *junciformis*, Cav.—Tel Abou Hereireh; Gaza.

**C. eleusinoides*, Kunth.—Frequent on the margins of the Arundo jungles, near the Dead Sea, in the Ghor es Safieh. Recorded only from Afghanistan in the Oriental region. A native of India, tropical Africa and Australia. An addition to the flora of Palestine.

C. papyrus, Linn.—Mr. Oliver could not be positive about this species, the specimens, owing to the season, being imperfect. The plant had not attained the full size of the papyrus, but in the floral characteristics they agree. The papyrus occurs at Lake Huleh, near Jaffa, and at Gennesaret; but not elsewhere indigenous nearer than Nubia. At Sicily it is believed to be anciently introduced. It occurred in the Ghor sparingly with the last species.

C. longus, Linn.—Ghor es Safieh; Tel Abou Hereireh.

C. rotundus, Linn.—Ghor es Safieh; Gaza.

C. schœnoides, Griseb.—Gaza.

Scirpus holoschœnus, Linn.—Jebel Musa; Wady el Tihyeh to Jebel Hertih. Not previously found in Sinai.

S. maritimus, Linn.—Ghor es Safieh; very variable.

Fimbristylis ferruginea, Linn.—Ghor es Safieh.

F. dichotoma, Rottb.—Ghor es Safieh.

Carex divisa, Huds.—Ghor es Safieh.

C. stenophylla, Wahl.; *β. planifolia*, Boiss.—Summit of Mount Hor; from Wady Zuweirah to Bir es Seba and Tel Abou Hereireh. Not found hitherto south of Gaza.

GRAMINEÆ.

Panicum teneriffæ, Linn.—Wadies Elain, Eltihyeh, and Araba; Akaba.

P. colonum. Linn.—Ghor es Safieh. Found hitherto at Sidon only in Palestine.

P. repens, Linn.—Gaza.

P. turgidum, Forsk.—Wady Elain, and in the Araba; Wady Zelegah; Akaba.

**P. molle*, *P. barbinode*, Trin., *forma*.—Jericho. Not included in Boissier's "Flora Orientalis." An addition to the flora of Palestine.

GRAMINEÆ—*continued.*

**Pennisetum dichotomum*, Forsk.—Wadies Nusb and Elain; Debbet er Ramleh; frequent in the Arabah. May be added to the flora of Palestine.

P. cenchroides, Pers.—Wady Haroun, and others leading into the Araba from Edom; Wady Arabah and Ghor es Safieh; Tel Abou Hereireh to Gaza.

Imperata cylindrica, P. de B.—Wadies Zelegah and Elain; Ghor es Safieh. Mentioned by Canon Tristram from Gennesaret under synonym I. aurundinacea, Cyr.

Saccharum ægyptiacum, Willd.—Wady Ghuweir. Known from Sidon and Beyrout in Palestine.

Erianthus ravennæ, P. de B.—Ghor es Safieh.

Sorghum halepense, Pers.—Ghor es Safieh. [*S. vulgare*, P., cultivated.]

Andropogon foveolatus, Del.—Akaba. Found in Egypt and S. E. Arabia, only in the Oriental region.

A. annulatus, Forsk.—Ghor es Safieh.

A. hirtus, Linn.—Summit of Mount Hor; Tel Abou Hereireh; Gaza.

Elionurus hirsutus, Vahl.; *Cælorachis hirsutus*, Brongn.—Common in Sinai, and extending to the edge of the Ghor.

Phalaris minor, Retz.—Jericho.

Aristida cærulescens, Derf.—Wady El Tihyeh.

A. ciliata, Desf.—Wadies Ghurundel and Araba; Ghor es Safieh.

A. plumosa, Linn.—Debbet er Ramleh; Wady El Tihyeh; Akaba, and along the Araba to the Ghor. A most beautiful little grass, with long feathery styles.

,, ,, *β. haussknechtii?*—In the Arabah near the Ghor.

A. obtusa, Del.—Wadies Nusb, Sudr, and Ghurundel (Elain); Debbet er Ramleh.

Piptatherum multiflorum, Beauv.—Wady es Sheikh; wadies on both sides of the Arabah and in the main valley.

**Sporobolus spicatus*, Vahl.—Ain Musa; near the mouth of a valley a few miles south of Gaza, apparently this species. An addition to the flora of Palestine. Not previously recorded north of Cairo, nor in Sinai or Palestine.

**Agrostis verticillata*, Vill.—Jericho, and near Bethlehem. An addition to the flora of Palestine.

Polypogon monspeliense, Desf.—Wady Elain; Ghor es Safieh.

Avena sterilis, Linn.—Jebel Abou Kosheibeh; Bethlehem.

**Danthonia forskahlii*, Vahl.—Wady Nusb; Debbet er Ramleh; Wady Araba, near the Ghor.

Cynodon dactylon, Pers.—Ghor es Safieh; Tel Abou Hereireh; Ramleh to Jerusalem.

,, ,, var.—Wady Ghurundel (Elim).

Phragmites communis, Trin.; *P. gigantea*, J. Gay.—Wadies Ghurundel (Elim) and Elain; Ain Abou Weirideh; Wady Zelegah; Ghor es Safieh. This species appears to have been called Arundo donax by several writers, especially in Sinai. In Wady Elain this gigantic species reached a height of fifteen feet.

Lamarckia aurea, Moench.—Jericho.
Koeleria phlæoides, Vill.—Jericho.
**Eragrostis pæoides*, P. de B.—Ghor es Safieh. An addition to the flora of Palestine.
**E. pilosa*, Linn.—Ghor es Safieh. An addition to the flora of Palestine.
**E. megastachya*, Link.—Ghor es Safieh. An addition to the flora of Palestine.
E. cynosuroides, Retz.—Abundant at Ain Fabal, near El Faba, in the Arabah; Ghor es Safieh; Gaza.
Schismus marginatus, P. de B.—Jericho.
Poa annua, Linn.—Ghor es Safieh; Tel Abou Hereireh.
P. ? sp., *P. sinaica*, R. ?—Zibb el Baheir and Jebel Watayeh, in Sinai.
Bromus madritensis, Linn.—Jericho.

Coniferæ.

Pinus halepensis, Mill.—Jerusalem.
Juniperus phœnicea, Linn.—Jebel Abou Kosheibeh; summit of Mount Hor; plentiful along the brow of the Edomitic limestone escarpment east of the Arabah, where it appears to be the main ingredient of a respectable growth of trees. Doubtfully mentioned by Tristram from Lebanon, but not elsewhere in Palestine. The present locality is in Boissier, partly.
Juniperus, (?) sp.—Bethlehem. Not in an identifiable condition.
Ephedra fragilis, Desf.—Wady Arabah, between Ain Abou Weirideh and the Ghor; Jericho; near Bab el Wad; Bethlehem, where specimens were gathered with inflorescence.
E. elata, Dcne.—Ain Abou Weirideh, near the Ghor. Apparently this species.
E. alte, C. A. Mey.—Summit of Jebel Musa; Wady Hessih and Jebel Hertih.

Equisetaceæ.

**Equisetum elongatum*, Willd.—Ghor es Safieh; Gaza. Five or six feet high in the Ghor.

Filices.

Ceterach officinarum, Willd.—Bab el Wad and Solomon's Pools, in Judæa; Jebbel Aou Kosheibeh and Mount Hor, in Edom.
Notholæna lanuginosa, Desf.—Wady Haroun and Jebel Abou Kosheibeh.
Cheilanthes fragrans, Linn.—Jebel Abou Kosheibeh and Mount Hor; Bethlehem and Bab el Wad.
Adiantum capillus-veneris, Linn.—Jebel Musa; Bethlehem.

CHARACEÆ.

**Chara hispida*, Linn.—Ain Abou Weirideh in the Arabah, and at Bir es Sowrah in Wady El Tihyeh.

MUSCI.*

Anisothecium (*Dicranum*) *varium*, Hedw.—Gaza, barren.
Grimmia apocarpa, Linn.—Jebel Musa, Jebel Catharine, barren.
G. leucophæa, Grev.—With the preceding, barren.
**G. trichophylla*, Grev.—Jericho; a few slender stems with very young fruit.
**G. pulvinata*, Linn.—Jericho.
**G. crinita*.—Mount Hor; Wady Musa.
Hymenostylium (*Gymnostomum*) *rupestre*, Schw.—Jebel Musa, Jebel Catharine, barren.
H. (*Eucladium*) *verticillatum*, B. & S., *Weissia verticillata*, Brid.—With the last, and barren.
**Tortula vinealis*, Brid.—Jericho, barren.
**T. unguiculata*, H. & T.—Gaza. A few barren stems.
**T. revoluta*, H. & T.—Gaza. Barren stems intermixed.
T. ruralis, Linn.—Jericho, with fruit; Bir es Seba; Jaffa. Piliferous.
T. membranifolia, Hook.—Jericho; Edom, with old fruit.
**T. inermis*, Mont.—Jebel Musa and Wady Haroun.
T. ambigua, B. & S.—Gaza; Mount Hor.
**T.* (*Trichostomum*) *rigidula*, Hedw.—Gaza, barren. Seems to be this species.
T. (*Trichostomum*) *tophacea*, Brid.—Mount Hor, barren.
**T.* (*Trichostomum*) *nitida*, Lindb.—Same locality as last.
**Encalypta vulgaris*, Hedw.—Jebel Catharine and Mount Hor.
Entosthodon templetoni, Schw.—Jebel Musa and Jebel Catharine.
Funaria hygrometrica, Linn.—Hospital of St. John, ruins; Jerusalem.
**Bryum argenteum*, Linn.—Jericho.
**B. atropurpureum*, W. & Mohr.—Jaffa; Bir es Seba; Jericho. Chiefly barren.
B. turbinatum, Hedw.—Jebel Musa; Jebel Catharine. Some others which will not revive are barren and uncertain.
Hypnum (*Brachythecium*) *ehrenbergii*, Lorentz.—Jericho.
H. velutinum, L.—Jebel Musa and Jebel Catharine.
H. ruscifolium, Neck.—Jebel Catharine.

* These mosses have been determined by Mr. William Mitten, F.L.S.

HEPATICÆ.

**Fossombronia angulosa*, Raddi.—Gaza.
**Otiona aitonia*, Corda.—Jericho. Certainly of this genus, probably this species.
**Lunularia vulgaris*.—Hospital of St. John, Jerusalem.
**Riccia lamellosa*, Raddi.—Bir es Seba.

N.B.—The majority of the above mosses and hepaticæ have not been previously known to inhabit Sinai or Palestine. They are almost invariably common Mediterranean species, the greater part being found in Britain. Lorentz, in the "Proceedings of the Berlin Academy," 1867, enumerated twelve species of those collected by Ehrenberg, 1820–26, in Egypt and Sinai; and Mons. Barbey in his "Herborization au Levant," Lausaune, 1882, gives a list of fifteen Palestine mosses and two hepatics, chiefly from Beyrout. Seven of Lorentz's and four of Barbey's are in my list. Decaisne, in the "Flora Sinaica," also gives four mosses from Sinai, of which two are not in my collection. Mr. Mitten was not aware of any Palestine mosses except those of Lorentz, and I have been able only to give the above further references. Altogether the total is forty-three mosses and six hepaticæ, but three of the mosses which Lorentz described as new may, according to Mr. Mitten, be found to be not so if good specimens were procured. Lorentz's specimens were all barren.

LICHENES.*

Omphalaria, sp. ?—Sterile and uncertain. Jebel Catherine, on rocks.
Ramalina crispatula, Nyl.—Sterile. On the ground at Bir es Seba. Distr. Canaries and N. Africa.
Cladonia pyxidata, L.—Sterile, and but little evolute. On the ground at Jericho. Cosmopolitan.
Lecanora (*Squamaria*) *crassa*, D. C.—Sparingly fertile. Amongst mosses on rocks in Wady Ghurundel (Edom). Distr. Europe, Africa, and Australasia.
Lecanora (*Sarcogyne*) *pruinosa*, Sm.—On rocks. Tih escarpment, near Wady Zelegah. Distr. Europe, N. America.
Endocarpon hepaticum, Ach.—On the ground. Ghor es Safieh. Distr. Europe, Africa, N. America.

* Several species from Wady Haroun do not appear in the above list, for which I am indebted to the Rev. James Crombie, F.L.S.

DESCRIPTION OF PLATES XV., XVI., AND XVII.

PLATE XV.

SKETCH MAP TO ILLUSTRATE ROUTE TAKEN.

PLATE XVI.

Fig. 1. GALIUM PETRÆ, sp. nov.

1*a*, flower in bud; 1*b*, flower open; 1*c*, pistil; 1*d*, stamen; 1*e*, stem and leaves: all enlarged.

Fig. 2. DAPHNE LINEARIFOLIA, sp. nov.

2*a*, flower open; 2*b*, section of flower; 2*c*, section of carpel; 2*d*, leaf: all enlarged.

PLATE XVII.

Fig. 1. BOUCEROSIA AARONIS, sp. nov.
Fig. 2. Stem.
Fig. 3. Flower, side view.
Fig. 4. Flower, front view.
Fig. 5. Flower bud.
Fig. 6. Stamens.
Fig. 7. Anther lobes.
Fig. 8. Carpels.

[Figures 2 to 8 enlarged.]

FORSTER & Co., Lith., DUBLIN

Hanhart imp

WH Fitch del. et lith.

1. Galium petræ, sp. nov.

2. Daphne linearifolia. sp. nov.

W.H.Fitch del. et lith.

Hanhart imp

Boucerosia aaronis.sp.nov

XX.—*On Three Circles related to a Triangle.* By W. S. M'Cay, M.A., F.T.C.D.

[Read, May 11, 1885.]

M. Brocard has shown, that if the sides of a triangle be taken as generators of three directly similar systems of points and lines, the locus of the intersection of three concurrent "corresponding" lines is a circle, and he has drawn many beautiful inferences from this theorem.

I propose to investigate some analogous properties of three collinear "corresponding" *points.** I shall use, as far as possible, the same letters as in the figures in M. Brocard's Paper (*Congrès d'Alger*, 1881), and, in addition, denote by P_{ac} or L_{ac} the c correspondent of P or L considered as an a point or line with reference to the triangle ABC.

1°. Any three corresponding points have the same centre of gravity (E) as the vertices of the generating triangle ABC.

This is most readily seen by Quaternions.

Let a, b, c be the vector sides of ABC, in order; ρ_1, ρ_2, ρ_3 the vectors from E to the vertices; then

$$\rho_1 + \rho_2 + \rho_3 = 0,$$
$$a + b + c = 0.$$

* Three points A', B', C', "corresponding" to the sides a, b, c of a triangle, may be considered vertices of three directly similar triangles described in the same aspect on the sides BC, CA, AB.

Three lines L, M, N, "corresponding" to the sides a, b, c, cut the sides BC, CA, AB in the same ratio (any ratio), and make equal angles in the same aspect with those sides.

Corresponding lines are made up of corresponding points.

Two a lines L_1, L_2 intersect at a point A' corresponding to the point B', the intersection of the two corresponding b lines M_1, M_2, and the angle between L_1, M_1, or L_2, M_2 is equal to C. Also the triangle formed by LMN is always similar to ABC. The length of the line joining two a points is to the length of the line joining the corresponding b points as $a : b$.

Let q be a quaternion operator whose axis is perpendicular to the plane of the triangle, then the vectors from the vertices C, A, B (or from any three "corresponding" points) to three corresponding points A', B', C' may be denoted by qa, qb, qc; for they start from "corresponding" points C, A, B (or B, C, A) respectively (*see* fig. 1), are proportional in length to a, b, c, and are inclined in the same sense to a, b, c, the inclination being the angle of the versor of q.

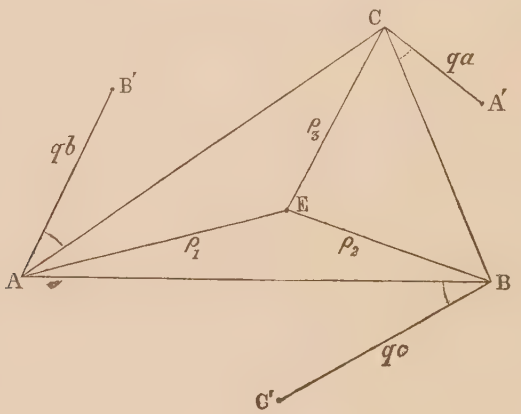

Fig. 1.

The vectors EA', EB', EC' being $\rho_3 + qa$, $\rho_1 + qb$, $\rho_2 + qc$, we have

$$EA' + EB' + EC' = \rho_1 + \rho_2 + \rho_3 + q(a + b + c) \equiv 0;$$

therefore E is the centre of gravity of A', B', C'. It is not difficult to prove this theorem (the fundamental one of the Paper) by elementary methods; but quaternions seem specially adapted for it. The method applies to a plane polygon of any number of sides.

M. Brocard gives the theorem for the particular case when A', B', C' are on the perpendicular bisectors of the sides of ABC; but I do not know if he was aware of the truth of the theorem in general.

2°. It immediately follows that *if A', B', C' be collinear, their line of collinearity always passes through E, their mean centre.*

3°. *And that A', B', C', when collinear, move on three "corresponding" circles intersecting at E.* For, if we seek to determine A', B', C' on any line L through E, the point A' will be given as the intersection of L with

L_{ca} (or L_{ba});* but since L passes through a fixed point E, L_{ca} also passes through a fixed point E_{ca}, and from the nature of "corresponding" lines L and L_{ca} intersect at a constant angle B, and therefore the locus of A is a circle which might also be generated as locus of vertex of a triangle standing on EE_{ba}, the vertical angle being C or its supplement. Hence the locus of A' is the circle $EE_{ba}E_{ca}$ (the triangle whose vertices are these three points is equiangular with ABC). The points B', C' will of course describe circles "corresponding" to that described by A'. I call the three circles the "A" circle, the "B" circle, and the "C" circle.

4°. *The three circles intersect on the Brocard circle at the double points* A_2, B_2, C_2 *of the three similar systems.*†

For, if C_3 be the c correspondent of C_2, then C_2, C_2, C_3 are three corresponding collinear points; therefore C_2 is on the "A" and "B" circles, and C_3 is on the "C" circle; and moreover, since E is the centre of gravity of C_2, C_2, C_3, $EC_3 = 2EC_2$; thus arriving immediately at a result otherwise obtained by M. Brocard. [M. Brocard shows that his circle passes through A_2, B_2, C_2—in fact, the three corresponding lines that intersect at C_2 are EC_3, $E_{ca}C_2$, $E_{cb}C_2$].

5°. If the point C' coincide with E, then $A'B'$ is a tangent at E to the "C" circle, and E is the middle point of $A'B'$, i. e. $E_{ca}E_{cb}$. It may be seen also that the three tangents at E are inclined to each other at angles A, B, and C (see fig. 4).

6°. The circles have their centres on the perpendicular bisectors of the sides of ABC. This of course might be expected. I will prove it by showing that the "C" circle passes through the reflexion of E with respect to the perpendicular bisector of AB.

Make the triangle BAC' (fig. 2. N. B. In this figure the letters A', B' should be interchanged) symmetrically equal to ABC, and the angles BCA', ACB', equal to A and B; then the triangles BCA', ACB', BAC' are similar corresponding triangles constructed on the sides of ABC, and their centres of

* Two corresponding points (say A', B') can be found on any line, but the third correspondent (C') will not be on the line unless it pass through E.

† A_2 is the point where a b point coincides with its c correspondent; it is the centre of similitude of the two lines CA and AB. The position of $A_2B_2C_2$ is shown in fig. 4.

gravity are therefore corresponding points; but they are on a right line

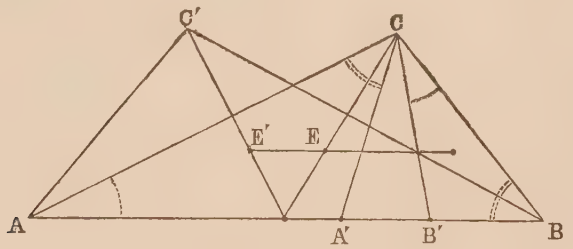

Fig. 2.

through E parallel to AB. Hence E', the centre of gravity of ABC', is on the "C" circle, and E, E' are reflexions with respect to the perpendicular bisector of AB.

7°. With a view to finding the centre and radius of one of the circles (say the "C" circle), I will show where the median through C cuts this circle again, E being of course one intersection. Calling L the median, there are three corresponding points, A', B', C' on it (2°). C' is found as in 3° by the intersection of L with L_{ac} or L_{bc}.

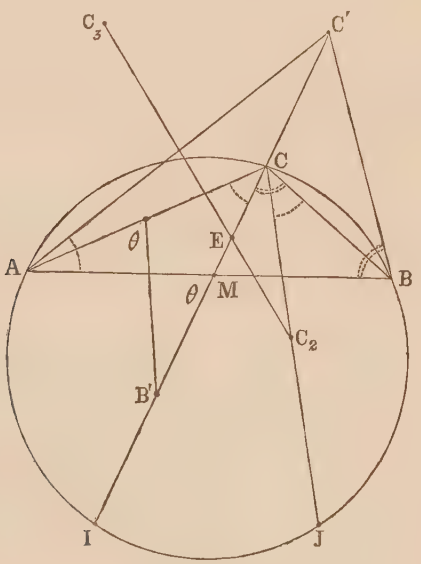

Fig. 3.

If then we make the angles BAC', ABC' equal to the adjacent segments

of the angle C made by the median; AC' and BC' are L_{bc} and L_{ac}, and we have by similar triangles

$$MC \cdot MC' = MA^2 = MC \cdot MI,$$

I being the point where the median cuts the circumcircle, whence a simple construction for C', namely, $MC' = MI$. Also, C' is the reflexion of C_3 (see 4°) with respect to the perpendicular bisector of AB, for M. Brocard shows that C_3 and I are reflexions with respect to AB. This result appears directly from the above figure (in a manner somewhat different from M. Brocard's). The double point C_2 is the common vertex of two directly similar triangles standing on BC and CA, and is on the symmedian* through C. Inspection shows that the triangles CBC_2 and ABC' are inversely similar. Hence if we take C'', the reflexion of C' with respect to the perpendicular bisector of AB, the triangles CBC_2 and BAC'' will be directly similar, and therefore $C'' = (C_2)_{ac} = C_3$, i. e. C_1, C_3 are reflexions, as stated.

The point C' on the median being found, its two correspondents A', B' are easily constructed: B' is got by drawing a line at the middle point of AC, making an angle θ equal to that at M; similarly A'. The lines joining C_2 to A' and B' are parallel to the sides BC and CA. (In the above figure E trisects C_2C_3, and C_2 bisects CJ.)

8°. We can now find the centre and radius of the "C" circle. Let d be the distance of the centre from M, and ρ the radius, θ the angle the median makes with AB, m the length of the median CM, t the tangent from M to the "C" circle; we have from 7°

$$t^2 = ME \cdot MC' = \frac{1}{3} MC \cdot MI = \frac{c^2}{12},$$

and $$2d \sin\theta = ME + MC' = \frac{m}{3} + t^2 \frac{3}{m} = \frac{1}{m}\left(\frac{m^2}{3} + \frac{c^2}{4}\right) = \frac{a^2 + b^2 + c^2}{6m}.$$

* The symmedians are lines through the vertices equally inclined to the sides with the medians; they intersect at the "Symmedian Point" K. The properties of this point have been much studied by Continental Geometers, notably by Lemoine and Neuberg. K is also the centre of perspective of ABC and the circumtangents at ABC.

But if α be the Brocard angle,*

$$\cot\alpha = \frac{a^2+b^2+c^2}{4\,.\,\text{area}} = \frac{a^2+b^2+c^2}{2c\,.\,m\sin\theta}.$$

Hence $$d = \frac{1}{6}c\cot\alpha\,;\ \rho = \sqrt{d^2-t^2} = \frac{1}{6}c\sqrt{\cot^2\alpha - 3}.$$

And for the other two circles we have only to change c to a or b.

The magnitude and position of the "C" circle depend only on c and α, whence the theorem—"Given of a triangle one side and the Brocard angle, the locus of vertex is a circle."† For the locus of the centre of gravity is a circle by the above.

9°. If we call h_1, h_2 the distances of the highest and lowest points of the "C" circle from AB, h_1, h_2 are roots of the quadratic equation

$$12h^2 - 4c\,.\,\cot\alpha\,.\,h + c^2 = 0$$

(from the values of ρ and d); or putting $h = \frac{1}{2}c\tan\phi$,

$$3\tan^2\phi - 2\cot\alpha\,.\,\tan\phi + 1 = 0\,;$$

and if ϕ_1, ϕ_2 be the roots of this equation, it is not difficult to prove that

* M. Brocard attributes the first announcement of the properties of the angle α to the *Problèms de Trigonométrie* of Leonce Clarke, 1849. In Hinds' *Trigonometry*, 4th ed., 1841, the equations

$$\cot\alpha = \cot A + \cot B + \cot C,$$

$$\operatorname{cosec}^2\alpha = \operatorname{cosec}^2 A + \operatorname{cosec}^2 B + \operatorname{cosec}^2 C,$$

are given as the results of the equation

$$\sin(A-\alpha)\,\sin(B-\alpha)\,\sin(C-\alpha) = \sin^3\alpha,$$

the geometrical interpretation of which is, that three lines through the vertices equally inclined at an angle α to the sides meet in a point.

There are two triads of such lines, and M. Brocard immediately deduces from his theorem that the points of concurrence for each ("Brocard Points") are on the Brocard circle, and that the lines pass in twos through the points A_1, B_1, C_1 (note to 10°).

† This result appears also at once from the equation $\cot\alpha = \frac{a^2+b^2+c^2}{4S} = \frac{a^2+b^2+c^2}{2cp}$, whence $4m^2 - 4cp\cot\alpha + c^2 = 0$. The equation of the "C" circle is

$$12\rho^2 - 4c\pi\cot\alpha + c^2 = 0,$$

ρ being drawn to middle point of base, and π the perpendicular on base.

$\alpha + 2\phi_1$ and $\alpha + 2\phi_2$ are supplemental, and that the quadratic itself may be written

$$\sin(\alpha + 2\phi) = 2\sin\alpha;$$

thus arriving at an equation given by M. Brocard for the common base angle of three *isosceles* triangles standing on the sides of ABC, and having the vertices (three corresponding points on the perpendicular bisectors of the sides) in one right line.

I will show presently (14°) the geometrical meaning of the supplemental angles $\alpha + 2\phi_1$, and $\alpha + 2\phi_2$.

The equation $\sin(\alpha + 2\phi) = 2\sin\alpha$ is equivalent to

$$\frac{\sin A}{\cos(A+\phi)} + \frac{\sin B}{\cos(B+\phi)} + \frac{\sin C}{\cos(C+\phi)} = 0;$$

for if P, Q, R be the collinear vertices of isosceles triangles just mentioned, and H the circumcentre, there will be

$$\frac{\sin A}{HP} + \frac{\sin B}{HQ} + \frac{\sin C}{HR} = 0,$$

and $HP = R\cos A - \frac{1}{2}\alpha \,.\, \tan\phi = \dfrac{R\,.\,\cos(A+\phi)}{\cos\phi}$, whence the above equation.

(The Brocard angle satisfies the equation $\sin A\,.\,\cos(A+\alpha) + \sin B\,.\,\cos(B+\alpha) + \sin C\,.\,\cos(C+\alpha) = 0$, as may also be seen geometrically from the Brocard circle $HA_1B_1C_1$ (10°)).

10°. Fig. 4 shows the relative positions of the circles to the sides of the triangle. The "C" circle passes through E, E_{ac}, E_{bc}, A_2, B_2, C_3, C', seven remarkable points about the triangle, and easily constructed. The points B, C', E_{ac} are in one right line, for the angles that BC' and BE_{ac} make with BA are equal. K is the symmedian point, and C_1K is parallel to AB. The characteristic of the three circles is, that any line through E cuts them in three points similarly situated with regard to AB, BC, CA, and on the same sides of these lines in vectorial order.

The Brocard circle passes through H, K, A_2, B_2, C_2 (double points), and A_1, B_1, C_1. The last three points are vertices of three isosceles triangles de-

scribed inwards on the sides with the Brocard angle α for common base angle, and are most simply constructed as intersections of parallels to the sides through K with the perpendicular bisectors of the sides. A_1, B_1, C_1 are ob-

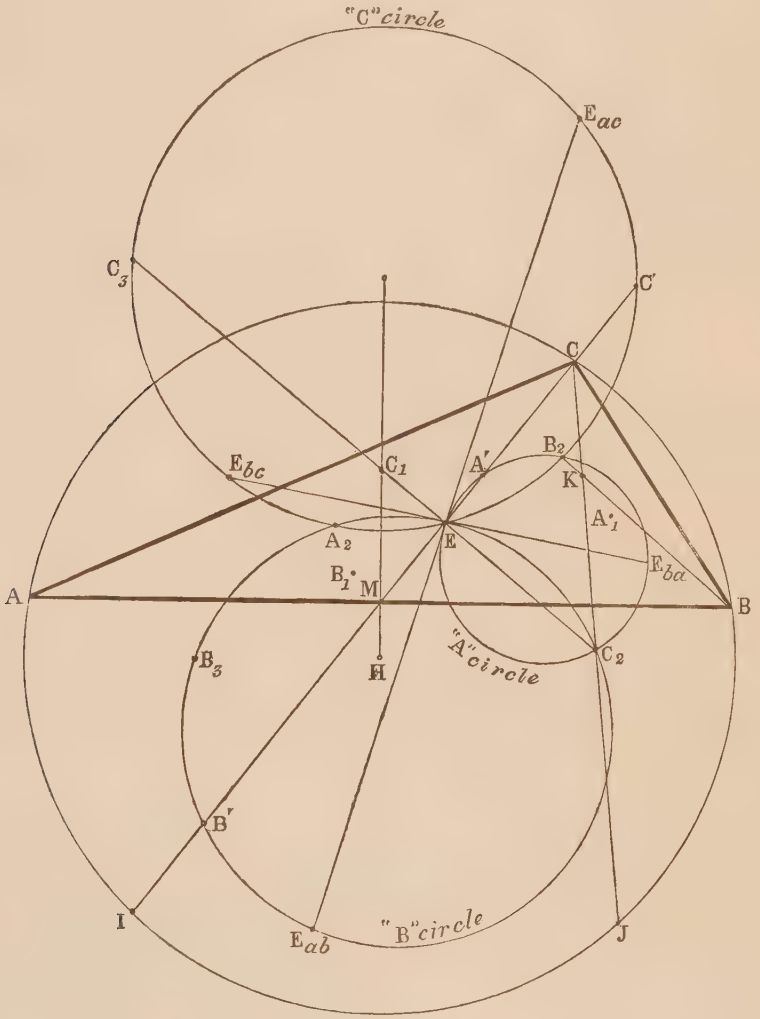

Fig. 4.

viously "corresponding" points. M. Brocard's theorem is, that if three right lines similarly situated with respect to the sides of a triangle meet in a point, then each of them must pass through one of the points A_1, B_1, C_1, and that

the locus of their intersection is the Brocard circle just mentioned.* The correlative theorem of this Paper is, "If three points similarly situated with respect to the sides of a triangle are in one right line, then each of them must lie on one of three fixed circles, and the line of connexion envelops a point."

The circles are related in a remarkable manner to the sides of the triangle and these points A_1, B_1, C_1. Let us consider the "C" circle and the side AB and C_1 only (see fig. 5).

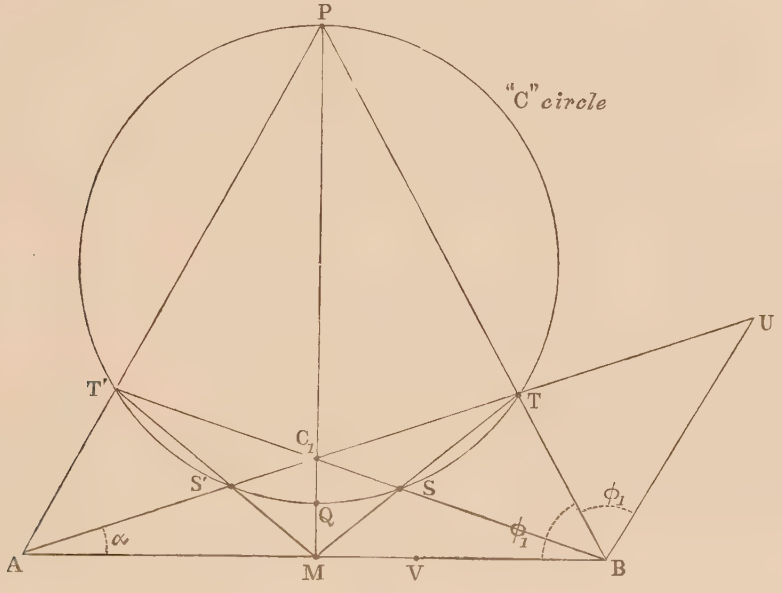

Fig. 5.

11°. C_1 is the pole of AB with respect to the "C" circle. Because from the first equation of 9° we have

$$\frac{1}{MP}+\frac{1}{MQ}=\frac{2}{\frac{1}{2}c\,.\,\tan\alpha}=\frac{2}{MC_1}.$$

* It is not difficult to perceive the truth of Brocard's theorem. Any three lines passing through A_1, B_1, C_1, and intersecting on the circle described on HK as diameter, are easily seen to be corresponding lines, as passing through corresponding points, and being equally inclined in the proper aspect to the sides. An immediate inference of M. Brocard's is that the line C_2EC_3, being one of a concurrent triad of correspondents (4°), passes through C_1.

12°. AC_1 and BP intersect on the circle. This is not so easily seen as the last. I will show that it is a consequence of the third form of the equation of 9°. Let AC_1 and BP intersect at T. Draw BU inclined at an angle ϕ_1 to BT. Then the equation $\sin(\alpha + 2\phi_1) = 2 \sin \alpha$ gives $AB = 2BU$, whence it follows that the figure $MBUT$ is a kite, and therefore the angle at M is equal to the angle at U, which is $\pi - (\alpha + 2\phi_1)$. Now take T', the intersection of AP and BC_1 (symmetric to T), and S, S', the symmetric intersections of MT, MT' with BC_1 and AC_1. Then the points S, S', T, T', P are on the same circle; for the angle BMT has been shown to be $\pi - (\alpha + 2\phi_1)$; therefore the angle $TST' = \pi - 2\phi_1 = BPA = TPA$; hence the points are on a circle. And since for the point Q we have $\sin(\alpha + 2\phi_2) = 2 \sin \alpha$, similar reasoning shows that the circle also goes through Q. And this circle coincides with the "C" circle, for BT is the external bisector of MTC_1; hence M and C_1 are inverse points, and therefore, by 11°, the circle is the "C" circle. In the same way AQS and BQS' are right lines.

13°. The hexagon $PTSQS'T'$ is such that the diagonals meet in a point, and pass each through an intersection of opposite sides.

14°. The angle $BMT = \alpha + 2\phi_2$, and $BMT' = \alpha + 2\phi_1$.

15°. Another property of fig. 4 is, that PS and $T'Q$ intersect in V, a point of trisection of MB, and V is the pole of $S'T$, and is also the centre of a circle through $S'TB$, this circle being the locus of the vertex of a triangle whose base is AM, and having one side double the other.

16°. Again, from the values of ρ and d in 8° it appears that a circle whose centre is M, and which passes through the centres of equilateral triangles above and below the base AB, cuts the "C" circle orthogonally, and therefore the centres of these triangles are limiting points of the "C" circle and the line AB, and the common chord of the two circles is KC_1, K being the symmedian point. Hence a simple construction for the "C" circle.

17°. Let 2ψ denote the angle between the tangents to the "C" circle from M: we will have

$$\cos \psi = \sqrt{3} \tan \alpha;$$

for, by 7°, the square of the tangent from M is $\frac{c}{2\sqrt{3}}$, and MC_1 (fig. 4) is $\frac{c}{2}\tan\alpha$, and C_1, M are inverses to the circle; hence the above equation. M. Brocard gives $\frac{\sqrt{1-3\tan^2\alpha}}{2}$ as the ratio of similitude of the triangles $A_1B_1C_1$ and ABC, and it now appears that this ratio is $\frac{1}{2}\sin\psi$. This result is easily verified; for, since E is the centre of gravity of both the similar triangles $A_1B_1C_1$ and ABC, their ratio of similitude is $\frac{EC_1}{EC}$, or $\frac{1}{2}\cdot\frac{EC_1}{EM}$. Now E is somewhere on the "C" circle (fig. 4), and $\frac{EC_1}{EM}$ is constant all round the circle, and equal to $\sin\psi$; C_1, M being inverses, and $\sin\psi$ the value of the ratio at a point of contact of a tangent from M; therefore

$$\frac{EC_1}{EC} = \tfrac{1}{2}\sin\psi = \tfrac{1}{2}\sqrt{1-3\tan^2\alpha}.$$

18°. If isosceles triangles be described inwards on the sides, with the complement of the Brocard angle α for common base angles; then the three circles (fig. 4) will have their centres at the centres of gravity of these isosceles triangles and the radii are the distances from E to these three centres.

19°. The vertices of these triangles (11) are in perspective with those of ABC at a point N, on the circumcircle of ABC, whose trilinear co-ordinates are

$$\frac{1}{\cos(A+\alpha)},\ \frac{1}{\cos(B+\beta)},\ \frac{1}{\cos(C+\gamma)}.$$

(M. Brocard has investigated properties of this point as an intersection of the circle with a certain equilateral hyperbola. He shows that N is in a right line with the circumcentre H and D, the centre of perspective of ABC and $A_1B_1C_1$.)

20°. N is also the point of concurrence of perpendiculars from the vertices of ABC on the sides of $A_1B_1C_1$. In fact N is situated similarly with respect to ABC as H is with respect to $A_1B_1C_1$.

21°. It may be seen from fig. 4, that if the Brocard circle ($A_2B_2C_2$, $A_1B_1C_1$) be inverted into itself from the point E, then the "C" circle inverts into

the line A_1B_1; hence the centres of the three circles are situated on the perpendiculars on the sides of M. Brocard's triangle $A_1B_1C_1$ from its centre of gravity, and the three tangents at E are parallel to the sides of $A_1B_1C_1$.

The sides of the triangle whose vertices are the three centres are proportional to the medians of ABC.

22°. The fundamental theorem, that any three corresponding points have E for centre of gravity, enables us to construct such a triangle $A'B'C'$ of any given species; for the ratios $EA' : EB' : EC'$ are given with the species: there will be two (and two only) solutions, as may be seen thus:

Let $EA' : EB' : EC' = l : m : n$, and using the notation indicated at first, we have, from the nature of corresponding points, $EA' : E_{ac}C' = a : c$; hence

$$\frac{E_{ac}C'}{EC'} = \frac{c}{a} \cdot \frac{l}{n},$$

and therefore one locus of C' is a circle. Similarly

$$\frac{E_{bc}C'}{EC'} = \frac{c}{b} \cdot \frac{m}{n},$$

and C' is determined as being either point of intersection of two circles, and A', B' are the a and b correspondents.

23°. If $A'B'C'$ be equilateral, then E being always the centre of gravity, is in this case also the circumcentre. Now there are only two such equilateral triangles by 22°, and we know where they are. If three equilateral triangles be described outwards on the sides of ABC, the centres of these triangles are known to be vertices of an equilateral triangle, and are obviously corresponding points. The other equilateral triangle is obtained from three equilateral triangles inwards on sides of ABC; and it was shown, in the *Lady's Diary* for 1865, that both these equilateral triangles have E for circumcentre—a result now seen to be an immediate consequence of the fundamental theorem of this Paper.

24°. Suppose the triangle $A'B'C'$ isosceles, with no other condition, C' being the vertex, we will have, as in 15°,

$$\frac{E_{ac}C'}{EA'} = \frac{c}{a}; \quad \frac{E_{bc}C'}{EB'} = \frac{c}{b},$$

and $EA' = EB'$; therefore

$$\frac{E_{ac}\,C'}{E_{bc}\,C'} = \frac{b}{a},$$

and we have the theorem that "the locus of a point equidistant from its two correspondents is a circle." This new circle is intimately related to the "C" circle (locus of a c point in line with its correspondents). Call the new circle the "γ" circle. We know four points on it. Two of them are the centres of equilateral triangles above and below the base AB. E must be a point on it also; for if C' be at E, E is the middle point of $A'B'$ by 1°. Again, the point C_3 (the c correspondent of the double point C_2 of the a and b systems) must be on this "C" circle, for here the side $C'A'$ actually coincides with $C'B'$. Moreover, the "C" and "γ" circles cut orthogonally at E and C_3: this follows from the fact that the two centres of equilateral triangles just mentioned are limiting points (16°) of the "C" circle and the right line AB (10°), and the "γ" circle passing through these, the circles cut orthogonally. The centre, then, of the "γ" circle is on AB, and is the pole of EC_3 with respect to the "C" circle (fig. 3), and divides $E_{ac}\,E_{bc}$ in the ratio $a^2 : b^2$.

25°. There are only two triangles of the kind (22°) similar to ABC; they are $A_1B_1C_1$, and the middle point of sides triangle of ABC.

26°. It is not difficult to extend the theorems of 2° and 3° to three homographic figures having two common double points.

Let $x_1\,y_1\,z_1$, $x_2\,y_2\,z_2$, $x_3\,y_3\,z_3$, be the trilinear co-ordinates of three corresponding points (see Salmon's *Higher Plane Curves*, p. 324). Then the condition of collinearity is

$$\begin{vmatrix} x_1 & y_1 & z_1, \\ x_2 & y_2 & z_2, \\ x_3 & y_3 & z_3, \end{vmatrix} = 0.$$

This in general gives a *cubic* curve for the locus of x_1, y_1, z_1 (the other co-ordinates being linear functions of x_1, y_1, z_1). But when there are two common double points to the three systems, let $z_1 = 0$ be the line joining them, and let $x_1 = 0$ pass through one of them, and $y_1 = 0$ through the other;

then the line $x_2 = 0$, and the others are of the form $x_2 = ax_1 + bz_1$, and the determinant becomes

$$\begin{vmatrix} x_1 & y_1 & z_1, \\ ax_1 + bz_1 & cy_1 + dz_1 & z_1, \\ ex_1 + fz_1 & gy_1 + hz_1 & z_1, \end{vmatrix} = 0.$$

The locus reduces to $z_1 = 0$, and a conic of the form

$$Ay_1z_1 + Bz_1x_1 + Cx_1y_1 + Dz_1^2 = 0,$$

which obviously passes through the two double points. Also the line of collinearity always passes through a fixed point; for if $lx + my + nz = 0$ be the line of collinearity, we will have the equations

$$lx_1 + my_1 + nz_1 = 0,$$

$$lax_1 + mcy_1 + (lb + md + n)\, z_1 = 0,$$

$$lex_1 + mgy_1 + (lf + mh + n)\, z_1 = 0.$$

Eliminating $lx_1 : my_1 : z_1$, an equation of the first degree only is left between l, m, n, and therefore the line passes through a fixed point. The envelope in general is of the third class.

The three systems* have, in pairs, three other double points, A_2, B_2, C_2. The coincidence of the first and second lines of the above determinant would give the point C_2; and of the first and third B_2; and of the second two lines, the point A_3 (3°); hence the "A" conic passes through B_2, C_2, A_3, and the two common double points. Also the "A" conic and its homographic correspondent conics, "B," "C," intersect at a *third* point (besides the two common double points), this point being the fixed point through which we have just seen the line of collinearity always to pass, for the co-ordinates of this point must satisfy the three equations last written; and eliminating l, m, n, we see it is on the "A" conic, and similarly on the other two.

* M. Tarry's extension of Brocard's theorem to three homographic systems having two common double points follows in a similar manner. M. Tarry's method (*Comptes rendus*, Avril, 1882) is very different. He notices that three corresponding points, when collinear, connect through a fixed point, but does not state that they describe conics.

When the two common double points are the circular points at infinity, we have three similar systems, and the conics become circles. It is to be noted, however, that there does not exist in general a triangle specially related to the system, like the triangle ABC (that is, a triangle having C, A, B for corresponding points, and also having B, C, A for corresponding points), from which M. Brocard generates the similar systems of his and this Paper. This is evident from the fact that taking three corresponding points of three similar systems and also three other corresponding points, the two sets of three need not in general have the same centre of gravity, which would be necessary if a triangle like ABC existed. Hence it appears that the theorem for homographic figures is more general than a projection of the theorem of 2° and 3°.

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27°. Since I communicated the foregoing to my friend Dr. Casey he has been considering the whole theory of points and lines "corresponding" to the sides of a triangle, from a purely analytical point of view, and he has arrived at elegant extensions of some of the theorems of this Paper.

28°. Dr. Casey finds among other results—

(*a*) "If the triangle $A'B'C'$ whose vertices are three corresponding points be of constant area, then the vertices move on three circles concentric with the "A", "B", and "C" circles."

(*b*) "If one angle (say C') of the triangle be constant, then C' describes a circle always passing through two fixed points as the constant varies, and A', B' describe circles 'corresponding' to that described by C'."

(*c*) "If the ratio of two sides (say $a' : b'$) of the triangle $A'B'C'$ be constant, then C' describes a circle belonging to a coaxal system as the constant varies, and A', B' describe 'corresponding' circles."

29°. These results follow readily from geometrical considerations. Let A', B' be two corresponding points of the a and b systems, and C_2 the double point; the triangle $A'C_2B'$ is of constant species (similar to CC_2A or BC_2C, fig. 4); hence a triangle $A'B'C'$ with corresponding points for vertices is such that the vertices being joined to $A_2B_2C_2$, the three triangles $A'C_2B'$,

$B'A_2C'$, and $C'B_2A'$ are of constant species. (A figure is easily made, or indeed fig. 4 might be used, taking the triangle CBA or BCA as a position of $A'B'C'$). The side a' of $A'B'C'$ is in a constant ratio to B_2C', and b' is in a constant ratio to A_2C', whence immediately Dr. Casey's theorem (c), and we see that the limiting points of the circles described by C' are A_2, B_2. The limiting points of the circles described by A' and B' are A_3, B_2 and B_3, A_2. The circle "γ" (24°) is the locus of C' when $a' : b' = 1$, and we now see another property of fig 4; for since the centre of the "γ" circle must lie on A_2B_2, therefore this line and $E_{bc}E_{ac}$ intersect on AB at the pole of EC_3 with regard to the "C" circle.

30°. Let the angle C' of the triangle $A'B'C'$ be constant; the angle $A_2C'B_2$ will be a given angle, only differing from C' by the sum (δ) of the angles $A_2C'B'$ and $B_2C'A'$ (28°), and the locus of C' is a circle always passing through A_2, B_2 (28° (b)). The vertices A', B' describe "corresponding" circles passing through A_3, B_2 and B_3, A_2 respectively. It should be noticed that for a given value of the angle C', the angle $A_2C'B_2$ may have *two* values. Taking A and B as two positions of the vertex C', it is not difficult to verify that $\delta = \pi - AEB$ (fig. 4), and that $A_2C'B_2 = AEB \pm C'$. The angles AEB and A_2EB_2 are obviously equal, for the latter angle is A_1EB_1, and E is similarly situated with respect to ABC and $A_1B_1C_1$ (10°, 25°). Hence $A_2C'B_2 = A_2EB_2 \pm C'$. The locus of C' is therefore *two circles* which coincide with the "C" circle (3°) when $C' = 0$ or π, and the two circles always cut "C" at the same angle (the angle being equal to C') at A_2, B_2. In the case where $C' = 90°$ the circles again coincide, and cut "C" orthogonally. At the points A_2, B_2 the value of the angle C' is indeterminate.

The case where the angle $C' = C$ is interesting, for in that case the Brocard circle is part of the locus of C', since it passes through A_2, B_2, C_1; and at C_1 the angle C' is equal to C, the triangles $A_1B_1C_1$ and ABC being similar. The other part of the locus is similarly seen to be the circle A_2B_2M (fig. 4). Of course the Brocard circle is also part of the locus of the vertices A', B' of the triangle $A'B'C'$, when $A' = A$, or $B' = B$. All the angles of $A'B'C'$ are equal to those of ABC in the case of the triangle $A_1B_1C_1$. Also the Brocard circle cuts the circles "A", "B", and "C" at angles equal to A, B, C, agreeing with the result in 21°.

31°. Let the area of the triangle $A'B'C'$ be constant (28° (a)), then $a'b'\sin C'$ is constant, and therefore $A_2C'.\ B_2C'.\ \sin(A_2C'B_2 \sim A_2EB_2)$ is constant (28°, 29°); and it may easily be seen geometrically that this product is equal to the "power" (P) of the point C' with respect to the circle A_2EB_2 (the "C" circle) multiplied by $\sin A_2EB_2$. Hence the locus of C' is two circles concentric with "C", and such that the power of any point on either with respect to "C" is the same. Taking the middle points of the sides of ABC as a particular case of the triangle $A'B'C'$, and observing that at the middle point of AB, $P = \frac{c^2}{12}$ (8°), we obtain an expression for the area of any triangle whose vertices are three corresponding points, viz.,

$$A'B'C' = \frac{3P}{c^2}ABC,$$

P being the power of the point C' with respect to the "C" circle.

Let the triangle $A'B'C'$ be $A_1B_1C_1$; P is equal to the square of the tangent from M (fig. 4) minus MC_1^2, that is, to $\frac{c^2}{12} - \frac{c^2}{4}\tan^2\alpha$, whence

$$A_1B_1C_1 = \frac{1 - 3\tan^2\alpha}{4}ABC,$$

thus again arriving at the expression for the ratio of these triangles (17°).

32°. If one side of the triangle $A'B'C'$ be constant, I find that the vertices again describe circles of concentric systems as the constant varies. Let the side $A'B'$ be given, the lengths C_2A' and C_2B' will be given (28°), and therefore A', B' describe circles with C_2 for centre, and C' describes a circle with C_3 (4°) for centre, since $C'C_3 : A'C_2 = c : a$.

The following expressions for the sides of the triangle $A'B'C'$ may be easily verified by taking BCA for a particular case: .

$$B'C' = \frac{2\lambda}{a}A'A_3;\ C'A' = \frac{2\mu}{b}B'B_3;\ A'B' = \frac{2\nu}{c}C'C_3,$$

λ, μ, ν being the medians of ABC. Any relation being given between the sides of the triangle $A'B'C'$, we can write down the equation of the locus of any of the vertices in terms of its distances from three fixed points. A relation of the kind $la'^2 + mb'^2 + nc'^2 = 0$, for instance, would lead to an

equation of the form $l'A'A_3^2 + m'A'B_2^2 + n'A'C_2^2 = 0$ for the locus of A'. This equation is known to represent a circle cutting orthogonally the circle $A_3B_2C_2$ (the "A" circle). [A_3 is found in the same way as C_3 (4°)].

33°. If any three "corresponding" circles be described with A_1, B_1, C_1 for centres, then *the triangle formed by any three "corresponding" tangents is of constant area.* This may be regarded as an extension of M. Brocard's theorem, and is easily seen. Parallels through A_1, B_1, C_1 to the three "corresponding" tangents (L, M, N) meet in a point K' on the Brocard circle (Brocard's theorem). K' is the symmedian point of LMN; for the perpendiculars (the radii of the three circles) from it on the sides are proportional to the sides, and these perpendiculars being of given magnitude, the triangle LMN is of given magnitude, and of course similar to ABC. This is a case of Bobilier's theorem. The vertices of LMN describe limaçons having the Brocard circle for a common generating circle.

34°. Dr. Casey notices a different extension of M. Brocard's theorem:—"The centre of similitude of ABC and the triangle formed by any three corresponding lines (L, M, N) is on the Brocard circle." The truth of this theorem may readily be perceived as follows:—

Let A', B', C' be the points where L, M, N cut the corresponding sides of ABC. Catalan's construction for the centre of similitude (O) of two lines (say AB and LM) gives O as the intersection of three circles $B'C'A$, $C'A'B$, $A'B'C$, and it is immediately evident, on making a figure, that $A'O$, $B'O$, $C'O$ are equally inclined to the sides, and are therefore concurrent corresponding lines (A', B', C' being of course "corresponding" points), and accordingly O must be on the Brocard circle.

35°. The two rectangular lines joining E to the highest and lowest points of the "C" circle (fig. 4) (which also pass through the "corresponding" extreme points of the "A" and "B" circles) are the axes of the maximum ellipse inscribed in ABC. For these axes are the rectangular pair of the pencil in involution determined by EA, EB, EC, and parallels through E to the sides. The intersections of this pencil with the "C" circle may be seen to be in perspective at C_1, whence the above result.

Note.—I find that the equations in the first note on p. 458 have been traced as far back as 1833, to Van Swinden. [Mr. Tucker, *Proc. Lond. Math. Soc.*, vol. xiv.]

XXI.—*On the Nitroprussides of the more important Bases of Opium.* By Edmund W. Davy, A.M., M.D., M.R.I.A., Professor of Forensic Medicine, Royal College of Surgeons, and Examiner in Medical Jurisprudence, Royal University, Ireland, &c.

[Read, April 13, 1885.]

For some time past I have been engaged in the study of a class of salts which have hitherto received but little attention; I allude to the Nitroprussides, or the compounds of nitroprussic acid [$H_2(NO)FeCy_5$] with different bases.

Those in the investigation of which I have been chiefly occupied, are certain undescribed organic salts of nitroprussic acid, more especially its combinations with the vegetable alkaloids or bases. I have already had the honour of communicating to the Academy in a Preliminary Report, which was published in its *Proceedings*,* an account of the nitroprussides of some of the most active and important of the vegetable bases, as those of strychnine, brucine, nicotine, and veratrine, as well as of quinine, cinchonine, and other alkaloids of the cinchona barks, and I purpose now bringing under notice the nitroprussides of the more important bases which occur in that very valuable drug and therapeutic agent, opium.

It is well known that opium is a most complex substance, which contains, amongst a number of other matters, several vegetable bases or compounds, which are capable of forming salts with acids, and it is to their presence that it owes its peculiar physiological and therapeutic effects.

* See *Proceedings of the Royal Irish Academy*, vol. iii. (second series, Science), p. 313.

Though a comparatively large number of such basic substances have been discovered in opium, still I have confined my attention to the following, viz. morphine, narcotine, narceine, codeine, thebaine, and papaverine, these being the only ones of any practical importance, as the others occur in very minute quantities, and some of them are even absent altogether from certain varieties of opium. Moreover, I have found that the bases which I have mentioned, are capable of forming more or less characteristic salts with nitroprussic acid, and consequently, that acid may usefully be employed in the identification and separation of those substances.

Morphine Nitroprusside $(C_{17}H_{19}NO_3)^2H_2(NO)FeCy_5 + H_2O$.

Commencing with morphine, the first-named alkaloid, it being the most abundant, and by far the most important of the opium bases, as it is to its presence chiefly that this drug owes its medicinal effects. I gave a brief notice of the nitroprusside of this base in the communication already referred to, but as I have since more fully studied this salt, as regards its preparation and properties, and have ascertained several new points connected with it, I think it right not to omit it in treating of the nitroprussides of the opium bases. This salt may be obtained, as I have already pointed out in the report referred to, by simply dissolving morphine, with the aid of a gentle heat, in nitroprussic acid, till a perfectly neutral solution is obtained, and this, on its concentration by evaporation, and subsequent cooling, will yield prismatic crystals of the salt. But though this method is so very simple, still as it necessitates the previous preparation of nitroprussic acid, which is rather troublesome, it is not so advantageous as the one I have subsequently found very convenient for its formation, and by which it may be readily obtained in considerable quantity. This consists in adding to a strong aqueous solution of morphine chloride a similar one of sodium nitroprusside, till the mixture acquires a tolerably deep reddish-brown colour, when, if the morphine solution be of sufficient strength, some of the salt may separate immediately, or if weaker, will slowly crystallize out in the form of light reddish-brown

prismatic crystals; and after it has thus formed, the fluid portion should be poured off, the crystals drained, and put on filtering paper, to remove as much as possible of the adhering solution containing the sodium chloride produced in the process, as well as any excess of sodium nitroprusside that might be present; after which the salt may be purified by being dissolved in hot distilled water, and recrystallized. I should here observe that when to a fully saturated cold aqueous solution of morphine chloride, sodium nitroprusside is added, or where a strong hot solution of the mixed salts is suddenly cooled, some of the morphine nitroprusside will immediately separate, as a dull yellow precipitate, which when examined under the microscope will be found to consist of very minute transparent spherical masses, closely resembling oil or fat globules, which, however, very quickly become crystalline, assuming different forms of crystallization. I may further remark, that I subsequently found the same phenomenon occurred whenever a strong hot solution of this salt was suddenly cooled, for it at first assumed this peculiar spherical condition, after which it quickly passed into the crystalline form.

This nitroprusside has a reddish-brown colour, and crystallizes generally in six-sided prisms, which are terminated either in pointed ends, or frequently as if broken across abruptly. This salt appears to undergo no change by exposure to the air, its crystals having retained their form and appearance, as well as sustained no gain or loss of weight, after long exposure to its action.

It dissolves sparingly and slowly in cold water, to which it communicates a faint brownish tint; it is, however, much more soluble in hot water, forming with it a light reddish-brown solution. From some experiments I made, I found that the dried salt required about 173 times its weight of water at the ordinary temperature, and only about 8 times when at the boiling point, for its solution.

This salt is also slowly soluble in rectified spirit, of which, when cold, it requires over 60 times; and when boiling, about 33 times its weight to dissolve it. In pure chloroform and anhydrous ether it is insoluble, and it is almost so in benzole and amylic alcohol.

I may here observe that the degree of solubility in water of this

nitroprusside, as well as of the others about to be described, was determined as follows:—A saturated cold solution was prepared by dissolving, with the aid of heat, some of the salt in water, and after leaving the solution for a day or so, that the excess might crystallize out, a certain quantity of this cold saturated aqueous solution was weighed in a counterpoised platinum capsule, and evaporated to perfect dryness, when the weight of this dried residue, deducted from that of the solution taken, gave the amount of water which had held this quantity of dried salt in solution; and this latter, divided into the former, represented the relative weight of the water required for the salt's solution. For the determination of the degree of solubility of the salt in water at the boiling temperature, the following simple modification of the method just described was found to answer the purpose:—A certain quantity of water was boiled for a few minutes with an excess of the salt, and some of this fully saturated boiling solution was quickly poured off from the undissolved salt into a counterpoised platinum crucible (furnished with a close-fitting cover), and placed on a large block of metal, or on an anvil, and after putting on the cover, a piece of metal was laid on the top of it, to cool the entire crucible and its contents as rapidly as possible; and when this was effected it was weighed, and the amount of solution taken ascertained, when, as in the former case, it was evaporated to dryness, and the weight of the residue determined; after which the degree of solubility was calculated as in the former case. I may further observe that where such determinations were made in the case of the volatile solvents used, that a light glass weighing-tube or bottle, furnished with a close-fitting stopper, was substituted for the platinum crucible, to obviate the loss of any of the solvent by volatilization during its cooling and weighing previous to evaporation. I would also wish to remark, that as many circumstances will affect to a certain extent the degree of solubility in different solvents of this, as of the other salts about to be described, that the amounts stated as to such are to be taken as approximate, and not as fixed and invariable quantities.

To determine the constitution of the morphine nitroprusside, a certain quantity of the air-dried crystals was taken and heated in a water-bath, or oven, till they ceased to lose any further weight, when the crystals, though

still retaining their form, were found to become more or less opaque and friable, showing that water had entered into the constitution of the salt in its crystalline state, and the loss of weight sustained by drying indicated the amount of its water of crystallization. The thoroughly dried salt was then, by the aid of a gentle heat, dissolved in distilled water, and a solution of silver nitrate added in excess, to precipitate its constituent nitroprussic acid as the insoluble silver nitroprusside [$Ag_2(NO)FeCy_5$], and this salt, so formed, was collected on a tared filter, washed, dried at 100° C., and then weighed, when from its weight the amount of nitroprussic acid in the quantity of the salt taken was readily ascertained. As to the morphine, it was determined by difference, that is to say, by deducting the amount of nitroprussic acid found, from the quantity of the perfectly dried salt taken, when the difference was regarded as the amount of that alkaloid. Taking 0·3 grams of the air-dried salt, and treating it in the way just described, the following results were obtained:—By heating in the water-bath the weight became 0·2935 grams, giving a loss of 0·0065 grams of water. The dried salt dissolved in water, and treated with silver nitrate, yielded 0·161 grams of silver nitroprusside, equivalent to 0·0812 grams of nitroprussic acid, and the morphine determined, as explained, amounted to 0·2123 grams.

These results agree almost precisely with the calculated quantities, which should be obtained from a salt having two molecules of morphine, combined with one of nitroprussic acid, and having one molecule of water of crystallization, as will be seen by comparing the following numbers:—

	Found.	Calculated.
	Grams.	Grams.
Morphine, ...	0·2123	0·2122
Nitroprussic Acid, . .	0·0812	0·0811
Water, ...	0·0065	0·0067
	0·3000	0·3000

The foregoing results agreeing so closely, there can be no doubt that this nitroprusside is correctly represented by the following formula:

$$(C_{17}H_{19}NO_3)^2H_2(NO)FeCy_5 + H_2O,$$

where two molecules of the base morphine are united to one of nitroprussic acid, forming a neutral salt, which in its crystalline state has one molecule of water of crystallization. I may further add, that from the experiments I have made, it does not appear that morphine is capable of forming an acid salt with nitroprussic acid. In this respect that base differs from nicotine, the active principle of tobacco, and from quinine, cinchonine, and some of the other alkaloids of cinchona bark, which have the property (as I have pointed out in the report referred to) of forming acid, as well as neutral salts, with nitroprussic acid.

Narcotine Nitroprusside $(C_{22}H_{23}NO_7)^2H_2(NO)FeCy_5 + 5H_2O$.

Narcotine, after morphine, is the most abundant alkaloid of opium, and possesses a slight hypnotic action; its nitroprusside will next be considered.

When to a salt of this alkaloid in solution, sodium nitroprusside is added, an immediate precipitate is produced, which at first is almost white, but quickly changes to a cream colour, and afterwards assumes a light reddish-brown appearance.

This precipitate is amorphous, and exhibits a great tendency to adhere to the sides and bottom of the vessel in which the mixture is made, and its particles agglutinate together to form there a somewhat resinous deposit which becomes of a reddish-brown colour.

Some of this salt, for its analysis, and the further examination of its properties, was prepared by dissolving, with the aid of a gentle heat, some narcotine in the smallest proportion of dilute sulphuric acid, and adding to the sulphate of the alkaloid so formed a solution of sodium nitroprusside, till no further precipitation was produced; and this precipitate, after its subsidence, and having adhered to the sides and bottom of the vessel, was

well washed with small portions of distilled water, till these washings ceased to become turbid on the addition of barium chloride; showing that the sodium sulphate formed in the reaction was completely removed. The narcotine nitroprusside was then drained, and removed from the vessel; after which it was placed on filtering paper, to separate any still adhering liquid, and was subsequently left for some time exposed to the air to effect its drying: when so prepared it formed a light reddish-brown resinous-looking matter, which was very brittle, and easily reduced to a powder of a much lighter shade of the same colour.

This nitroprusside is sparingly soluble in water at the ordinary temperature, requiring, as it does, about 192 times its weight of that liquid for its solution, which, when thus fully saturated, has only a very faint brownish tint. Heat, however, very much increases the solvent power of water for this salt, as it requires only about $13\frac{1}{2}$ times its weight of boiling water to effect its solution; and, when so dissolved, it communicates to it a tolerably deep reddish-brown colour.

I may here observe that when it is slowly heated with water, before dissolving, the greater part of the salt fuses, and becomes perfectly liquid at about 70° C., forming a heavy dark reddish-brown oil-like liquid, which remains at, or sinks to the bottom of, the vessel; and by continuing the heat, if sufficient water is present, completely dissolves, producing a solution of the colour just mentioned. The air-dried salt, however, when in powder, and slowly heated in a water-bath, did not fuse, its particles merely becoming slightly coherent; but when the salt, not quite so dry, was quickly heated, it fused at first on the application of heat. This salt dissolves pretty readily in rectified spirits, requiring about $6\frac{1}{2}$ times its weight at the ordinary temperature, and only about 3 times at the boiling point for its solution; but it is far more soluble in chloroform, which appears to be its best solvent, as it was found to require only about $2\frac{1}{2}$ times its weight of that liquid for its solution, even at the ordinary temperature. It is only very slightly soluble in benzole and amylic alcohol, and appears to be insoluble in anhydrous ether.

In order to determine the constitution of this salt, 0·4 grams of it which had been dried in the manner already explained were taken, and

heated in the water-oven till no further loss in weight occurred, when the perfectly dried salt amounted to 0·363 grams, indicating a loss of 0·037 grams of water of hydration.

To determine the nitroprussic acid, the dried salt was taken and dissolved, by the aid of heat, in distilled water, and that acid precipitated by the addition of silver nitrate, when 0·155 grams of silver nitroprusside were obtained, equivalent to 0·078 grams of nitroprussic acid; and the narcotine, determined in the way already explained, amounted to 0·285 grams. The foregoing results as to the amounts of nitroprussic acid, narcotine, and water, agree very closely with the calculated quantities which should by theory be obtained, from a salt containing as in the case of the morphine nitroprusside, two molecules of the base combined with one of the acid; but in this latter salt, when in its hydrated condition, having also six molecules of water, as is shown by the following numbers:—

	Found.	Calculated.
	Grams.	Grams.
Narcotine, ...	0·285	0·287
Nitroprussic Acid, . .	0·078	0·076
Water, ...	0·037	0·037
	0·400	0·400

These results agreeing so closely, there can be no doubt that the constitution of this nitroprusside is correctly represented by the following formula:

$$(C_{22}H_{23}NO_7)^2H_2(NO)FeCy_5 + 6H_2O,$$

where two molecules of the base are united to one of the acid, forming a neutral salt, which, as precipitated and air-dried in the manner described,

contains six molecules of water of hydration. I may further observe that narcotine does not appear to be capable of forming either a crystalline or an acid salt with nitroprussic acid.

Codeine Nitroprusside $(C_{18}H_{21}NO_3)^2H_2(NO)FeCy_5 + 6H_2O$.

The alkaloid codeine (which has been used in medicine to some extent on account of its hypnotic effects) is another of the opium bases capable of forming a neutral salt with nitroprussic acid. This nitroprusside may be produced by simply dissolving, by the aid of a gentle heat, codeine to saturation in nitroprussic acid, and subsequent evaporation of the liquid. It was found, however, that it could be more advantageously obtained by decomposing a warm solution of codeine sulphate with one of barium nitroprusside, the salt being thus produced by double decomposition. In preparing it by this process, the barium nitroprusside was added to the codeine sulphate, till neither salt was in excess, which was indicated by a little of the clear liquid, after the subsidence of the barium sulphate formed, not giving any precipitate or turbidity when tested with either a drop or two of dilute sulphuric acid, or with that of a solution of barium chloride. The codeine nitroprusside being in solution, was separated from the insoluble barium sulphate by allowing the latter salt to subside completely, or removing it by filtration; after which the solution was somewhat concentrated by evaporation, when on cooling, a viscid semiliquid film formed on the top in oil-like globules. The mixture being left for a day or so, and exhibiting no indications of crystallizing, it was then evaporated to dryness, when a brown resinous mass was obtained, which, when pulverized, formed a light brownish-coloured powder.

The salt, so prepared, is tolerably soluble in cold water, of which it requires about 74 times its weight for solution, and, when dissolved in it to this extent, it communicates to it a deep reddish-brown colour. It is, however, much more soluble in hot water, as only a little over 4 times its weight when at the boiling point effects its solution.

In rectified spirit it is still more soluble, for about $16\frac{1}{2}$ times its weight when cold, and only a little over $1\frac{1}{2}$ times when boiling, will dissolve it; but it appears to be insoluble in anhydrous ether, pure chloroform, and benzole.

It was found that when this salt in its viscid condition was left in contact with water for several days, it assumed an opaque reddish-white appearance, and acquired a granular consistence, evidently from some molecular change taking place in its particles, or in consequence of its combining with water, and thus passing into a more or less crystalline condition; indeed, from some observations I have made, it appears that this salt, under certain conditions, which I have not yet determined, is capable of assuming a crystalline form.

To determine the constitution of this salt, some of that which had acquired the opaque appearance just described, and which had been dried by contact with filtering paper, and subsequent exposure to the air, was selected for analysis, and of such 0·25 grams were taken. This, on heating in the water-bath, lost 0·028 grams; and the dried salt, amounting to 0·222 grams, was then dissolved in distilled water by the aid of heat, and silver nitrate added in slight excess, to precipitate its nitroprussic acid, as silver nitroprusside, when the quantity of that salt found was 0·116 grams, equivalent to 0·058 grams of nitroprussic acid. The codeine estimated, as already explained, amounted to 0·164 grams.

These results as to the proportions of nitroprussic acid, codeine, and of water, agree very closely with the theoretical quantities that should by calculation be obtained, from a salt consisting of two molecules of the base united to one of the acid, and having six molecules of water in its hydrated condition, as is seen by comparing the following numbers.—

	Found.	Calculated.
	Grams.	Grams.
Codeine, ...	0·164	0·163
Nitroprussic Acid, . .	0·058	0·058
Water, ...	0·028	0·029
	0·250	0·250

The closeness of the results found with the calculated quantities, as is shown by the foregoing, leave no doubt that the constitution of this salt, in its hydrated condition, is correctly represented by the following formula :—

$$(C_{18}H_{21}NO_3)^2H_2(NO)FeCy_5 + 6H_2O.$$

Narceine Nitroprusside $(C_{23}H_{29}NO_9)^2H_2(NO)FeCy_5 + 5H_2O$.

Narceine, another of the opium bases, and one possessing considerable somniferous properties, is capable of forming a neutral salt with nitroprussic acid.

This compound was obtained by the same process as that employed in the case of the codeine nitroprusside, viz. by adding to the narceine sulphate a solution of barium nitroprusside—when the insoluble barium sulphate separated, leaving the narceine nitroprusside in solution. This latter, after the complete subsidence of the former, was poured off and concentrated by evaporation ; when on cooliug, the greater part of the salt separated as a soft viscid reddish-brown matter remaining on the surface of the liquid, which, on standing for some time, became opaque and granular. This was then taken, and after being washed several times with small portions of distilled water, was drained, and placed on filtering paper to remove adhering moisture, and was then exposed to the air to effect its drying. On this appearing to be accomplished, it was reduced to powder, when it formed one of a light-yellow colour.

This salt is sparingly soluble in cold water, of which it requires nearly 172 times its weight to dissolve it, and this cold saturated aqueous solution has only a very faint brown tint. It is, however, much more soluble in hot water, as only about 34 times its weight of that liquid at the boiling point is necessary to effect its solution, when it forms one of a brownish colour.

I may here observe that the air-dried salt, when slowly heated under water, fuses into a reddish-brown mass, which becomes quite fluid at about 70° C. In rectified spirits, at the ordinary temperature, it dissolves rather slowly, requiring something over 29 times its weight of that liquid for its

solution; but when at the boiling point only about $2\frac{1}{2}$ times its weight are sufficient to dissolve the salt, and on cooling this solution the greater part of it separates in the form of tufts of minute prismatic crystals. It dissolves very sparingly in pure chloroform, but is insoluble in anhydrous ether and benzole.

To determine the constitution of this nitroprusside, 0·3 grams of the air-dried salt were taken and heated in the water-bath, when the loss of water amounted to 0·023 grams. The dried salt, weighing 0·277 grams, was then dissolved, by the aid of heat, in distilled water, and its contained nitroprussic acid determined under the form of silver nitroprusside, as in the case of the preceding salts, when the quantity obtained of that compound corresponded to 0·053 grams of nitroprussic acid, and the narceine, estimated in the manner already explained, amounted to 0·224 grams.

These results as to nitroprussic acid, narceine, and water, agree very closely with the quantities of those substances that should, by calculation, be obtained from a salt having, like the preceding nitroprussides, two molecules of the base united with one of the acid, and which in its hydrated condition contains five molecules of water, as is shown from the following numbers:—

	Found.	Calculated.
	Grams.	Grams.
Narceine, ...	0·224	0·225
Nitroprussic Acid, . .	0·053	0·053
Water, ...	0·023	0·022
	0·300	0·300

The very close agreement of the above numbers leaves no doubt that

the composition of this salt, in its hydrated condition, as obtained in the manner described, is correctly represented by the following formula:

$$(C_{23}H_{29}NO_9)^2H_2(NO)FeCy_5 + 5H_2O),$$

where two molecules of narceine are combined with one of nitroprussic acid, and that in this hydrated condition it contains five molecules of water.

Thebaine Nitroprusside $(C_{19}H_{21}NO_3)^2H_2(NO)FeCy_5 + 4H_2O$.

The next nitroprusside of the opium bases which I shall describe is that of thebaine, an alkaloid which, strange to say, belongs to those poisons, the most prominent effects of which are the tetanic spasms they produce; and in this respect its action closely resembles that of strychnine. The nitroprusside of this alkaloid was prepared by adding to a solution of thebaine sulphate one of sodium nitroprusside, when an abundant amorphous precipitate of a dull yellowish-white colour was immediately formed, the particles of which had a great tendency to agglutinate together, and adhere to the sides and bottom of the vessel in which the mixture was made.

The sodium salt being added till no further precipitate was produced, the liquid was poured off, and the precipitate, placed on filtering paper, was well pressed, to remove as much as possible of the adhering liquid containing the sodium sulphate formed, as well as of any sodium nitroprusside remaining in excess. It was then gently heated along with a small portion of distilled water, when it fused, at about 40° C., into a reddish-brown resinous-looking mass, which, on increasing the heat, became quite mobile, forming a heavy oil-like liquid of the same colour, that remained at the bottom of the vessel. This was then shaken about in the water, to wash it, after which the mixture was allowed to cool, so that the salt might solidify, when it (as well as that portion of this nitroprusside which had

been dissolved by the aid of heat reprecipitating) adhered firmly to the sides and bottom of the vessel, as a soft adhesive resinous-looking matter. This, after removal, was placed on filtering paper, to separate all adhering moisture, and on exposure to the air for a short time became so brittle as to be easily reduced to powder; after which it was again left in contact with the air for some days, stirring it from time to time to insure its complete air desiccation; when it formed a dull light-yellow powder.

This salt is very sparingly soluble in water at the ordinary temperature, requiring, as it does, just 293 times its weight for solution; but heat increases very much the solvent power of water for this salt, as it dissolves in only about 35 times its weight of boiling water. As to its solubility in rectified spirit, it requires about $8\frac{1}{2}$ times its weight of that liquid at the ordinary temperature, and a little over 3 times, when boiling, to dissolve it; but its readiest solvent appears to be chloroform, of which, at the ordinary temperature, about 10 times its weight quickly effects its solution. It is slightly soluble in amylic alcohol at the ordinary temperature, but is somewhat more so in it when heated; and this solution, on again cooling, becomes turbid, or milky in appearance, from the separation of some of the salt in minute oil-like globules or particles. In benzole it is soluble only to a very slight extent, and it appears to be quite insoluble in anhydrous ether.

To determine the constitution of this nitroprusside, 0·35 grams of the air-dried salt, in the state of powder (prepared as before described) were taken, when after being dried in the water-bath the loss was found to be 0·029 grams. This thoroughly dried salt was then dissolved, by the aid of heat, in distilled water, and its contained nitroprussic acid determined by its conversion into the insoluble silver nitroprusside, when the quantity obtained was equivalent to 0·083 grams of nitroprussic acid. The thebaine estimated, as in the case of the preceding salts, amounted to 0·238 grams.

These results will be found to agree very closely with the theoretical quantities of nitroprussic acid, thebaine, and water, which should be contained in the amount of salt taken, where such consisted of two molecules

of the base united to one of the acid, and having four molecules of water of hydration, as will be seen on comparing the following numbers:—

	Found.	Calculated.
	Grams.	Grams.
Thebaine, ...	0·238	0·239
Nitroprussic Acid, . .	0·083	0·083
Water, ...	0·029	0·028
	0·350	0·350

The foregoing agreeing so closely, there can be no doubt that the constitution of this salt, in its hydrated condition, as obtained in the manner described, is correctly represented by the following formula:

$$(C_{19}H_{21}NO_3)^2H_2(NO)FeCy_5 + 4H_2O.$$

where two molecules of thebaine are combined with one of nitroprussic acid, and that the salt, so formed, unites with four molecules of water in the hydrated condition in which it was obtained.

Papaverine Nitroprusside ($C_{20}H_{21}NO_4)^2H_2(NO)FeCy_5$.

The last of the opium alkaloids that I shall notice (and one that seems to possess some hypnotic effects), is papaverine, which is capable of forming a neutral salt with nitroprussic acid. This compound is produced on adding to a solution of a papaverine salt one of sodium nitroprusside, when, if the mixture be made at the ordinary temperature, and the papaverine salt be not too dilute, an immediate yellowish-white, or buff-coloured precipitate is formed, which at first is amorphous, but on standing some time becomes

more or less crystalline. If, however, the solutions be hot, there is no precipitate at first produced, but the mixture, on cooling, becomes turbid, and afterwards again gets clear, whilst a crystalline deposit, consisting of tufts of prismatic crystals, make their appearance on the sides and bottom of the vessels containing the mixture. Some of the salt was prepared for examination by treating papaverine sulphate with sodium nitroprusside, the latter being added in slight excess—washing the precipitate so formed, first by decantation, and then on a filter, till the filtrate did not produce any turbidity when tested with barium chloride. It was then allowed to dry by exposing it to the action of the air, first while on the filter, and subsequently after being placed on a watch-glass. As so prepared, it exhibits itself as a dull yellowish-white powder, which, though appearing amorphous, is found to be more or less crystalline when seen under the microscope. This salt is by far the least soluble in both cold and hot water of the nitroprussides of the opium bases, as it requires about 3752 times its weight of cold, and nearly 260 times of boiling, water for its solution. It is, however, much more soluble, though still sparingly so, in alcohol, requiring about 443 times its weight of rectified spirit at the ordinary temperature, and about 75 times, when boiling, to dissolve it; and from the alcoholic solution, by slow evaporation, tufts of prismatic crystals are obtained. It is but very slightly soluble in pure chloroform and amylic alcohol, and is still less so in benzole, whilst it is quite insoluble in anhydrous ether.

To determine its constitution, 0·2 grams of the air-dried salt, prepared in the manner just stated, were taken, and heated for some time in the water-bath; but on subsequent weighing it was found that no loss in weight had been sustained, showing that this salt contained no water of crystallization, or hydration, and in this respect was unlike the other nitroprussides of the opium bases, all of which contained more or less of water in either of those conditions.

This salt was then dissolved, by the aid of heat, in distilled water, and its contained nitroprussic acid precipitated by the addition of silver nitrate in slight excess, when the quantity of silver nitroprusside obtained was equivalent to 0·052 grams of nitroprussic acid, and the papaverine estimated, as in the case of the preceding salts, amounted to 0·148 grams.

Comparing these results with the theoretical quantities which should, by calculation, be obtained from the amount of the salt taken, supposing it to consist of two molecules of the base, united to one of the acid, they are found to come pretty near, as will be seen from the following numbers:—

	Found.	Calculated.
	Grams.	Grams.
Papaverine, ...	0·148	0·151
Nitroprussic Acid, . .	0·052	0·049
	0·200	0·200

And I may further remark, that the agreement in these results not being closer, might possibly be due to the chemical formula of papaverine ($C_{20}H_{21}NO_4$) taken, not representing the exact composition of that base, as there is still some difference of opinion regarding it; but be this as it may, there can be no doubt that this nitroprusside consists, as the preceding salts, of two molecules of the base combined with one of the acid, as is expressed by the following formula:—

$$(C_{20}H_{21}NO_4)^2H_2(NO)FeCy_5.$$

General Observations.

The foregoing investigations show that the bases of opium mentioned, form with nitroprussic acid, salts which are more or less sparingly soluble in water at the ordinary temperature, though their degree of solubility in that liquid is very much increased by heat. This is remarkably so in the case of the morphine salt, which requires 173 times its weight of cold water, whilst about 8 times, at the boiling temperature, effects its solution.

Morphine is the only one of these bases which seems to be capable of forming a readily crystallizable salt with nitroprussic acid—the others being either quite amorphous, or exhibiting, only under particular circumstances, a slight tendency to assume a crystalline condition. Some of these nitroprussides, when heated gently under water before dissolving, fuse and become quite liquid at a temperature much under that of boiling water, and on cooling they assume a resinous condition, easily reducible to powder. The salts described exhibit, too, some differences as regards the action of certain solvents, especially that of chloroform, which readily dissolves the narcotine and thebaine salts, but only very sparingly so those of narceine and papaverine; whilst those of morphine and codeine appear to be quite insoluble in that liquid. From these, and some other differences which I have observed in the nitroprussides of the alkaloids mentioned, I am of opinion that nitroprussic acid may be usefully employed in effecting their separation from each other; and possibly also in the estimation of the amount of morphine contained in different samples of opium, which are matters of some practical importance, in the study of which I am still engaged.

XXII.—*Alphabetical Catalogue of the Earthquakes recorded as having occurred in Europe and adjacent Countries, arranged to serve as a basis for an Earthquake Map of Europe.* By Joseph P. O'Reilly, C.E., Professor of Mining and Mineralogy, Royal College of Science, Dublin.

[Read, 13th April, 1885.]

When submitting to the Academy in April, 1884, a Catalogue of Earthquakes as a basis for an Earthquake Map of the British Islands (these "Transactions," *ante* p. 285), I was then already engaged on the preparation of a similar Catalogue for Europe and the adjacent countries. This I have now the honour to submit to the Academy. As it has involved much labour, and is more detailed in certain respects than that for Great Britain and Ireland, some remarks upon it may not be out of place.

The main object kept in view in this, as in the previous Catalogue, has been to furnish a sufficient basis for an Earthquake Map in this case of Europe and adjacent countries, relatively to frequency of occurrence and extent of district affected; these characters to be expressed, as on the map accompanying the catalogue already published, by conventional tints of one colour (carmine), graduated proportionally to ascertained frequency of occurrence and extent of district or locality affected.

Earthquake Maps of parts of Europe have been published; but as the methods of representation employed were not, so far as I have been able to ascertain, based on figures, as in the present case, they could only be approximate, and would represent rather the outcome of individual appreciation than a graphic representation of facts or figures: such a map could not be controlled or verified satisfactorily; whereas any map based on the present Catalogue will allow of such control and verification, so necessary for the requirements of Science at the present time.

The authorities consulted have been, as in the previous Catalogue, Mallet, Perrey, and Fuchs; and were it not that in Perrey's lists the supplements are frequent and are distributed over many volumes of 'Proceedings' (principally in the *Mèmoires couronnés de l'Académie Royal de Belgique*), the present Catalogue would allow of references being easily made to these lists, and details worked out with regard to any given locality and year.

As these lists may be considered as containing the main facts required in the present case, it is hoped that this Catalogue will sufficiently serve the immediate purpose had in view—that is the graphic representation of the seismic actions having affected Europe and the adjacent countries during historical time, or rather during the period covered by the Greek and Roman and Modern histories. May we not hope that the extraordinary progress of the study of Eastern monuments and records will supplement these histories by data on natural phenomena which Science may be enabled to turn to advantage?

I have purposely included many places outside Europe in the Catalogue, because geologically it is very difficult to define where the limits of the map should be drawn, and because the coasts of Northern Africa, Syria, Egypt, Asia Minor, and even of the Black Sea countries, are so intimately connected with Europe proper both physically and geologically, that no sharp line of delimitation can be usefully drawn.

Owing to changes in the modes of spelling geographical names, to changes even of the names, to the difference of names according to languages used, to insufficient indications of locality, to incorrect spellings, and other causes of error, a certain number of places mentioned in the lists consulted could not be identified. To enable the identification to be made, it has been found necessary to give in the greater number of cases the district and country of the place mentioned, particularly when there are several of the same name, as is frequently the case.

It is certainly remarkable that events of the magnitude and importance of earthquakes have not been more regularly and more generally noted and recorded. The examination of this Catalogue shows how incomplete our records are in this respect down to the middle of the last century or

thereabouts, even for Europe, and enables us to estimate the gaps which it may never be possible to fill up.

The instances in this respect are numerous and striking. Thus the records of the Abruzzi commence in the year 1641, and thenceforth shocks are recorded as being frequent and violent. For Adrianople the data commence in 1509, and shocks are frequent subsequently. The northern coast of Africa shows a record commencing in 1069; the next is in 1170, and is noted as having extended to Sicily; the next is in 1531, and thenceforth the mentions become more frequent.

For Bâle the records are relatively complete, and go so far back as 856 the first date recorded; and judging from the frequency of the shocks subsequently up to the present the same frequency must have existed prior to 856, and have extended back even into geological times, or to the very commencement of the uplifting of the Alps; so that what we have as records can only be an almost infinitely small part of the sum of earthquake actions having manifested themselves at Bâle.

For Albania the record commences in 1667; and yet it is clear from the subsequent details and from what is known of that country that earthquake action must have been both frequent and violent during preceding times.

The same observation would apply to the Syrian coast, and still more strongly to Asia Minor, and indeed to the whole of the Mediterranean basin. For Epirus, the first record given is 1807, with the following observations by Pouqueville: "The most earthquake country of Europe."

For Bourbonne les Bains, with the date 1780 (the first recorded on the lists consulted), appears the note, "a shock is probable every two or three years."

For Agram the records commence in 1502; subsequently the shocks are frequent and often violent.

It is greatly to be regretted that for the eastern part of the Mediterranean basin detailed and complete records are wanting, since, judging by those we have of recent earthquakes in this district, the frequency and the intensity of the shocks must have been relatively great, and their influence

on the gradual formation of the present outline of the Mediterranean must have been great, and would have been most interesting to trace.

The examples of the imperfectness of the records might be multiplied, but sufficient has been given to show how meagre and how unequal in detail they are, generally speaking, even for Europe.

When we examine them, and when we note how many countries, localities, and cities or towns have been devastated or utterly ruined, and what loss of life has frequently ensued, may we not infer that these events have been far more potent social factors than is usually supposed, that they deeply affected the prosperity of nations and the relative predominance of peoples and cities, and that in all probability they have given rise to sudden migrations of whole populations at certain periods of history, the causes of which seem to be inexplicable up to the present; finally, that they deeply tinctured the beliefs and traditions of certain races in remote times, and, in some shape or form, lie deep in their legendary history, as it has come down to us? These considerations seem to me to give to any grouping of these great events a certain value, even as regards the matter of sound historical research, wherein every factor has to be taken into account, so far as possible, if the true reading of the results is to be arrived at.

From the very nature of an earthquake shock, the observation of it can hardly be made under satisfactory conditions; hence correct and complete observations must be the exception, particularly so as regards the very violent and therefore important events.

Beyond the fact of a shock or of shocks having occurred in a given place on a certain day and hour, the other data must, in the very great number of cases, be matters of purely personal appreciation, and most frequently be either very imperfect or altogether wanting. It is thus that as regards relative intensity, nature and direction of the movement, number of distinct shocks, and limits of action, details are generally wanting. Wherever the direction of movement of undulation has been recorded it is given in this Catalogue, and these data, presented as they are in a condensed form for each locality or district, are of considerable geological interest. In the cases where fissuring has been produced the details are

summarily given. Such a result may be said to generally accompany shocks of any appreciable force, although the fissures may be imperceptible. When these result from an undulatory movement of the ground, their direction should be perpendicular to that of the movement of undulation, and their depth and extent in some way proportional to the violence of the shock and to the area affected thereby.

Had we for every earthquake a record of the direction or directions of undulation observed or observable in the localities affected, we would be justified in expecting to find systems of fissures or joints perpendicular to these directions, and developed proportionally to the intensities of the shocks. Certain of these systems of fissuring would appear to be more important than others, and would affect more deeply the rock structure of the locality. Furthermore, if the point affected be an island or land bordering the sea, or a lake, we might expect to find a relation between its coast-line directions and the directions of undulation recorded in respect of the earthquakes having occurred there. This may be illustrated in the case of the Island of Candia or Crete. Its record commences in 365, and shocks have been noticed throughout the subsequent centuries up to the present. The directions of oscillation or undulation have not however been recorded for these data. But if we take those of the town of Canea, the capital, we find nine shocks recorded as having given rise to an east-to-west or west-to-east motion (implying therefore fissuring in a north-to-south direction), and nine shocks having given rise to undulations in a north-to-south direction (corresponding to fissuring in an east-to-west direction). We have no indication as to the relative intensities of these two classes of shocks; but it can be already inferred that the island might be expected to present coast-lines running in two main directions, east to west and north to south, and such is really the case.

Furthermore, it is to be observed that the length of the island relatively to its breadth is somewhat as the length of the Mediterranean between Tunis and Syria to the breadth between the Morea and the opposite coast of Africa. From this it would not be excessive to infer, that the most violent shocks in the Mediterranean have been those giving rise to north-to-south undulations, and that they largely contributed to bring about the present

form of that sea. This example will show the importance attaching to the indications of these directions of oscillation, and fully justifies the interest presented by the study of systems of jointing and fissuring as traces or records of past earthquake action, which study I have ventured to call the attention of the Academy to as of very great importance for Geology.

As regards the intensities of the shocks the records are necessarily imperfect even at present. The most careful observations in this respect cannot be expressed otherwise than by a conventional scale, such as that adopted by the Italian *savants*. This embraces ten degrees of intensity. Of these, No. 1 corresponds to a microseismic motion, only perceptible by trained observers having the command of a seismograph. The last, No. 10, implies great intensity with destructive effects, fissuring of the earth, &c. (see Tschermack's *Mineralogische Mittheilungen*, New Series, 5th vol., part iv., p. 367.) This scale is hardly in use yet outside of Italy.

It being therefore impossible to indicate the relative intensities for each particular case, mention has only been made of the degree of intensity when the shocks are recorded as "violent" or "very violent;" and when more marked results are recorded these are summarily added. For brevity sake "violent" is indicated in this Catalogue thus, *1843*; and "very violent," thus, **1844**. To these are added details when of marked importance, such as limits of shock, fissuring, changes of level caused, damage done, lives lost, &c. In order to express the extension of a shock to the environs of a locality, the fact is noted thus, 1833 R = 15 kilometres, implying that a shock having taken place in a given locality in the year 1833, it extended to the environs over a distance represented by a circle having a radius of 15 kilometres.

The unit employed all through, so far as possible, has been the shock. An earthquake may be represented by one shock or more; it is therefore the number of shocks which has, so far as possible, been counted in the Catalogue. It is necessary, however, to explain that the number of shocks for a given locality and date are rarely exactly given in the records. The terms—"a shock," "shocks," "many shocks," "numerous shocks," even "continuous shocks," or "shocks continuous" for so many days or

months, continually recur. It has been necessary to assign some numerical value to these various terms; and in order to be strictly within the limits of truth they have been estimated as follows:—The terms "shocks" simply is taken as meaning at least two; "many shocks" as at least implying three; "very many shocks" or "numerous shocks," as implying four. For the expression "continuous shocks" or "shocks continuous" during a given period, it is taken for granted that *at least* one shock occurred per day during the period indicated. This will explain the frequency of such records as 1834 + 2; 1835 + 3; 1850 + 1. When a definite number of shocks is mentioned for a certain place and year it is noted thus, say, 1797 + 7, meaning eight shocks for the place indicated in the year 1797, the main and essential point being, to simplify and reduce the indications to what is strictly necessary for the determination of a figure showing the relative frequency of seismic action for a given locality or place.

It is evident that failing to express the intensity as well as the number of shocks, there must result a certain distortion or disproportion in the graphic representation to be employed. Thus to take an instance, Carlsruhe shows a record of eighty-two shocks up to 1880; Casa Micciola, Ischia Island, a record of fourteen up to 1881; but the intensity in the latter case is expressed by the partial destruction of the town, and would imply a much greater total amount of energy than that represented by the sum of eighty-two shocks for the former. Nevertheless, as the intensity cannot be expressed, nor indeed estimated, it must be omitted in the method of representation to be employed.

This distortion or disproportionate representation is unavoidable at present, and diminishes somewhat the value of the Map to be constructed simply on the numerical datum of frequency of occurrence, but only as regards certain places, the seismical importance of which is well known, and for which therefore allowance can always be made. The Map to be constructed on this Catalogue will involve considerable time and trouble in the execution, and, consequently, I venture to submit the present Catalogue by itself to the Academy, in the hope that it may be found useful from the historical and geological points of view which I have endeavoured to point out.

ALPHABETICAL CATALOGUE OF EARTHQUAKES RECORDED AS HAVING TAKEN PLACE IN EUROPE AND ADJACENT COUNTRIES.

[For brevity sake, "violent" is indicated in this Catalogue thus, "*1843*," and "very violent" thus, "**1844**;" to these are added details when of marked importance, such as limits of shock, fissuring, change of level caused, damage done, lives lost, &c. In order to express the extension of a shock to the environs of a locality the fact is noted thus, "1833," R = 15 km., implying that a shock having taken place in a given locality in the year 1833, it extended to the environs to a distance represented by a circle having a radius of 15 km.]

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
AACHEN, ...	Rhenish Prussia, . .	(*see* Aix-la-Chapelle).	—
AALEN, ...	Wurtemberg, . . .	1861.	1
AAMODT, ...	Osterdale, Sweden, . .	1819.	1
AARAU, ...	Aargau C., Switzerland, .	1756; 1840; 1851; 1855+1; 1856+2; (1858+1) E.–W.; 1861; 1863 N.W.–S.E.; 1879+1; 1881+3.	18
AARBERG, . . .	Berne C., Switzerland, .	1777.	1
AARBURG, . . .	Aargau C., . . .	1873 S.E.–N.W.	1
AARGAU CANTON, . .	. . . . .	1755+1; 1856+1.	4
AAR. GLACIER, . .	. . . . .	1846.	1
AARHAUS, . . .	Jutland, ...	1788.	1
ABANO, ...	Padua, ...	1882.	1
ABBADIA, . . near	Hendaye (B. Pyrenees), .	1869; 1874.	2
ABBEVILLE, . . .	(Somme) France, . .	1765.	1
ABBEYDORE, . . .	Hereford, ...	1853.	1
ABBIATEGRASSO, . .	Pavia, Italy, . . .	1755.	1
ABERBARDEN, . near	Hereford, ...	1853.	1
ABERDEEN, . . .	. . . . .	1608; 1816.	2
ABETO, . . . near	Norcia, Roman States, .	1859+1.	2
ABINGTON, . . .	Cambridge, ...	1683; 1771.	2
ABWINKEL, . . .	Tegern (*see* Bavaria), . .	1873, fissure opened 5 km. long and four feet wide.	1
ABONG, ...	Hungary, ...	1870; 1871.	2
ABRIES, ...	Piedmont, ...	1808.	1
ABRUZZI, ...	Italy, ...	1641; 1703; 1706; 1711; 1730: **1731**+5; 1742; 1787+3; 1791; 1809; 1858; *1881*, extended to Naples; more than 1000 houses destroyed.	20
ABRUZZO CITERIORE, .	. . . . .	1840+3; **1857**+8.	13
ABRUZZO ULTERIORE, .	. . . . .	1842+2.	3
ABFALTERSBACH, . .	. . . . .	1848.	1
ABRIES, ...	(H. Alpes), ...	1808+29.	30
ABTENA, ...	Saltzbourg, . . .	1861 S.E.–S.W.	1
ACCRINGTON, . . .	Lancaster, ...	1869.	1
ACHAIA, ...	Greece, ...	62.	1
ACHALKALAKI, . near	Alexandropol, Caucasus, .	1853; (1868+42) S.–N., +4.	48

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ACHALZIEH,	Caucasus,	(1844 + 9) S.–N.; 1868.	11
ACHERN,	Baden, S.W. Germany,	1871.	1
ACI-CATENA,	Sicily,	1867; 1868.	2
ACIREALE,	Sicily,	1865 + 3; 1866 + 1; 1867 + 9; 1868 + 3; 1869 + 1; 1870 + 3; 1871 + 2; 1874; 1875 + 1; 1880 + 9; 1881 + 2.	45
ACKERMANN ISLANDS,	Kherson, S.W. Russia,	1868.	1
ACQUASPARTA,	Ombria, Italy,	1871 + 26.	27
ACRE,	Palestine,	1303.	1
ADALIA,	Anatolia,	1863 + 1.	2
ADDERBURG,	Oxford, England,	1731; 1838.	2
ADELBODEN,	Berne C.,	1846.	1
ADELSBERG,	Carniola,	1866 + 1; 1870 + 2; 1872 S.E.–N.W.; 1873 S.E.–N.W.; (1876 + 1) S.–W.; 1879 + 1.	11
ADIGE RIVER VALLEY,	Italy,	1876.	1
ADJUD,	Moldavia,	1878 + 2; 1880; 1881 N.–S.	5
ADLER,	Blk. Sea Coast, W. of Caucasus,	1870.	1
ADMONT,	Judenburg, Styria,	1825 + 1; *1826 + 3*; 1855 N.E.–S.W.; 1856 N.E.–S.W.; 1857 + 7 + 1 S.W.–N.E.; 1860 E.N.E.–W.S.W.; 1862; 1866 + 3.	23
ADORF MINE,	Saxony,	1860.	1
ADORF,	Voighland, Saxony,	1770; 1789 N.W.–S.E., + 2; 1862.	5
ADRA,	Almeria, Spain,	1861 + 1.	2
ADRAMITI GULF,	Anatolia,	1867 + 1.	2
ADRIANOPLE,	Rumili, Turkey,	1509; 1752 + 1, simultaneously at Constantinople, + 1 + 1 + 6; 1754; 1762; 1766; 1829 + 22; 1855, extended over a surface enclosing Smyrna, Adrianople, Broussa, Gallipoli, Constantinople, direction S.W.–N.E. + 3; 1859 + 8; 1860; 1863 + 1; 1867 + 3; 1869 + 1; 1870; 1877 + 1; 1881 + 3.	65
ADRIATIC SEA,		1303; 1843.	2
,, ,,	Coast of,	1837.	1
,, ,,	Italian Coast of,	1667.	1
,, ,,	Northern Coast of,	1875.	1
ÆDYPSOS,	Eubea, Greece,	1869 + 31.	32
ÆGENA ISLANDS,		1830 + 1.	2
ÆGEAN SEA,	Archipelago, Greece,	1876.	1
ÆRENDORF,	Bavaria,	1879.	1
ÆSCH,	Bâle, Switzerland,	1701.	1
ÆTOLIAN COAST,		1882 + 3.	4
ÆTOLIKO GULF, Coast of,	Missolonghi, Greece,	1882 + 3.	4
AFFAJA,	Cataluña, Spain,	1845 + 1.	2
AFFROUN,	Algeria,	1869.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
AFIUM KARA HISSAR, .	E. of Smyrna, Anatolia, .	1862 + 9; 1869.	11
AFLENTZ, . . .	Styria, ...	1856 + 1 S.E.–N.W. + 1.	3
AFORD HOUSE, . .	7 miles W. of Hazelmere, [Hampshire,	1864 + 1.	2
AFRICAN COAST, . .	Northern, ...	1069; 1170, extended to Sicily; 1531; 1541, stopped the expedition of Charles V. against Algiers; 1723; 1724; 1773 + 19; 1790, extended simultaneously to Spain; 1804; 1833, extended to Carthagena.	29
AGARD, ...	Hungary, ...	1881 + 1.	2
AGATHICUNI, . . .	. . . . .	494.	1
AGEN, ...	(Lot et Garonne), France.	1815 + 3; 1854.	5
AGGERSCHUNS, . .	Amt., Norway, . . .	1757 + 1.	2
AGHADOE, . . .	Co. Cork, Ireland, . .	1820.	1
AGNONE, ...	Frosinone, Italy, . .	1256; 1881.	2
AGORDO, ...	Belluno, Italy, . . .	1859 N.N.W.–S.S.E.	1
AGORIANI, . . .	Parnassus, Greece, . .	1866 + 1.	2
AGRAFA, . . .	Eurytania, Greece, . .	1867.	1
AGRAM, ...	Croatia, ...	1502, most of the buildings destroyed; 1564; 1659; 1686; 1756; 1757; 1812; 1822; 1827; 1830; 1832; 1834 N.E.–S.W.; 1836; 1837 N.–S. + 2; 1839; *1840*; 1843 + 1; 1848; 1851; 1852 + 4; 1853; 1854; 1855 N.E.–S.W.; 1856 S.E.–N.W.; **1857** S.S.E.–N.N.W.; 1858; 1861 + 2; 1865; (1868 + 2) N.E.–S.W.; 1869 N.N.E.–S.S.W.; 1870 + 3 E.–W.; 1871; (1872 + 10) N.E.–S.W.; 1876; 1877 + 1 W.–E.; (1879 + 3) W.–E. + 1 + 1 W.–E.; **1880** (Nov. 9th)—Limits: N., Krems; E., Pesth and Esseg; S., Serrajewo, Pola, Padua; W., Goritz and Klagenfurt; a smaller central zone of action parallel to the Save valley, N.E.E.–S.S.W.; numerous clefts opened and mud thrown out, one cleft 19 yards long and 3 yard sbroad; the chief cleft crossed the Save below Derinje. The whole cleft system had an extension of half a-league and a direction S.E. to N.W. + 4 + 1 N.–S. + 55; 1881 + 2 N.E.–S.W. + 1 S.E.–N.W. + 20; 1882 + 2 + 2 S.E.–N.W., extended into Croatia, Montenegro, greater part of Hungary, and Bosnia, + 2.	158
AGRAMONT, . . .	Cataluña, ...	1852 N.–S.	1
AGUILAS, LAS, . .	Mediterranean, Spain, .	1863.	1
AHUM, ...	Creuse, France, . . .	1855.	1
AHLER-HÜTTE, . near	Lahnstein, Nassau, . .	1869.	1
AHRWEILER, ...	Rhenish Prussia, . .	1869 S.–N.	1
AIAGUZ, ...	Kirghis Steppe, . . .	1848.	1
AIDIN, PROVINCE, . .	Anatolia, Asia Minor, . .	1861 N.–S. + 8; (1862 + 1) N.N.E.–S.S.W.; 1863; 1867.	13
AIDIN-GUZEL-HISSAR,	. . . . .	1859 + 1; 1860 + 1; 1861; 1869, focus at Montéché, facing the Sporades; 1880.	7
AIGION, ...	Doris, Greece, . . .	1860 + 3; *1861* + 20, the town devastated, the sea rose 30 feet over its ordinary level; 1862; 1866.	27
AIGNAY-LE-DUC, . .	Côte d'or, France, . .	1783.	1
AIGUILLON, . . .	Lot and Garonne, . .	1814.	1
AIGUEBELLE, . . .	Maurienne, Savoy, . .	(1847 + 2) N.–S.; 1849 + 1.	5

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
AIGUEPERSE, . . .	Puy de Dôme, . . .	1838.	1
AIGUILLON-SUR-MER, .	Vendée, ...	1852.	1
AIGUECHERAL, . .	Caucasus, ...	1869.	1
AIGLE, ...	Valais, Switzerland, . .	1572; 1577; 1601; 1661; 1712; 1755; 1756 + 1; 1812; 1851; 1874; 1879; 1880; 1881 + 4.	18
AIGNAY-LE-CHATEAU, .	Allier, France, . . .	1857.	1
AIGUE BLANCHE, . .	Savoy, ...	1855.	1
AIN-BEIDA, . . .	Constantine Prov., Algeria, .	1859 W.–E.	1
AINE, Department, . .	France, ...	1851; 1881.	2
AIN-HAMADÉ, . .	Syria, ...	1849 + 1; 1850; 1855.	4
AIN-TRIK, . . near	Setif, Algeria, . . .	1863.	1
AIX, ...	Provence, France, . .	1617; 1678; 1763; 1786; 1808; 1818 + 1; 1822; 1825; 1847 + 1.	11
AIWALY, ...	Anatolia, ...	1837; 1859 + 3; 1867; 1870.	7
AITON, ...	Maurienne, Savoy, . .	1847; 1849.	2
AIX, ...	Savoy, ...	1755 + 2; 1784; 1823 + 1; 1855 E.–W.; 1881 + 1.	9
AIX, Pays d', . . .	Bouche du Rhône, . .	1227; 1678 + 3; 1808 + 1; 1818.	7
AIX, Department, . .	France, ...	1877.	1
AIX LA CHAPELLE, .	(Aachen), Rhenish Prussia, .	803; 823; 1756; 1759 + 1; 1818 + 2; 1828 + 2 S.E.–N.W. + 1; 1846; 1857 S.E.–N.W. + 1; (1859 + 2) N.W–S.E.; 1868 + 3; 1877; 1878 + 4; 1879 + 5; 1881 N.–S.	35
AJOLA, . . . near	Sienna, Italy, . . .	1871.	1
ALA, ...	South Tyrol, . . .	1877; 1879 N.E.–S.W. + 1; 1880 + 1; 1881 + 1.	7
ALAIS, ...	Gard, France, . . .	1814.	1
ALANCO, . . .	North Italy, . . .	1818.	1
ALAND ISLANDS, . .	Baltic, ...	1823.	1
ALASSIO, ...	Albenga, Italy, . . .	1882.	1
ALATRI, ...	Frosinone, Italy, . .	1873; 1880 W.–E.	2
ALB, ...	Baden, ...	1878.	1
ALBA, ...	Lombardy, Italy, . .	1771 + 3; (1878 + 1) E.–W.	6
ALBINE LAKE, . .	Italy, ...	B.C. 900.	1
ALBANIA, ...	. . . . .	1667; 1756; 1838 + 1; 1843; 1851 + 14, two thousand people killed, + 3; 1856; 1858 + 20.	45
ALBANIA, Southern, .	. . . . .	1858.	1
ALBANO, ...	Rome, Italy, . . .	1750; 1752; 1756; 1762; 1764; 1766; *1784* + 6; 1788; 1799 + 3; 1801; 1818 + 1; (1819 + 1) S.E.–N.W.; 1821; 1829 + 14 + 8; 1837 + 2; 1839 + 2; 1867 + 2; 1869; 1873.	58
ALBANS, ST., . . .	Herts, England, . . .	1250.	1
ALBARRACIN, . . .	Aragon, Spain, . . .	1817.	1
ALBENA, ...	North Italy, . . .	1882.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ALBENGA,	Italy,	*1831*; 1871 E.–W.	2
ALBERTVILLE,	Maurienne, Savoy,	1847; 1852 + 1.	3
ALBI,	Tarn, France,	1770; 1822.	2
ABIER-LE-JEUNE,	Maurienne, Savoy,	(1839 + 49) S.E.–N.W.	50
ALBONDON,	Almeria Prov., Spain,	1863 + 2.	3
ALBOX,	Andalusia,	1863 + 13.	14
ALBSTADT,	Swabia,	1786 + 3.	4
ALBUFEIRA,	Portugal,	1856 + 5.	6
ALBUÑOL,	Andalucia, Spain,	(1804 + 4) S.–N.; 1863 + 2.	8
ALCACER,	Portugal,	1858.	1
ALCAMO,	Sicily,	1823.	1
ALCANTRA,	Portugal,	*1757*, extended to Lisbon, Viana on the Tagus, and especially Evora.	1
ALCOCER,	Estremadura, Spain,	1817.	1
ALDERLY, near	Southhampton,	1878.	1
ALDUDES, LES,	B. Pyrenees, France,	1860 + 1.	2
ALDWICK,		1824.	1
ALEANELLO,	Basilicata,	*1858*.	1
ALEPPO,	Syria,	1138 + 30, shocks lasted two months; 1139; **1616**; 1666; 1719 + 3; 1726 E.–W. + 2, extended to Alexandretta; 1759 + **11** + 30; 1760 + 1; 1764; 1778; 1795 N.–S. + 1; 1822 + 450 + 33; 1831; 1846; 1864; 1868 W.–E., compasses deranged; 1870; 1872; 1877.	580
ALESSIO,	Albania,	1860.	1
ALENÇON,	Orne, France,	1775 + 1; 1814; 1827; 1853.	5
ALEXANDRIA,	Egypt,	794, The Pharos overturned; 1303; 1687 + 10; 1754; 1822; 1845 + 2 + 1, extended to Syria; 1846, extended to Malta and Sicily, + 1; (1847 + 1) E.–W., + 1; 1856 + 2; 1863 + 2; (1865 + 1) W.–E.; 1868; (1870 + 2) S.E.–N.W.; 1879.	36
ALEXANDRETTA, or Iskanderun,	Adana, Asia Minor,	1726 + 2; 1872.	4
ALEXANDROPOL,	Caucasus,	1840; 1856; (1868 + 10) S.–N. + 3 E.–W. + 1 S.E.–N.W. + 2; (1869 + 2) W.–E.	22
ALFTER, near	Bonn,	1824.	1
ALGAMITAS, Rocas de,	near Oluna, Spain,	1862.	1
ALGESIRAS,	Spain,	1822; 1834; 1868.	3
ALGARVE, Province,	Portugal,	**1755 + 3**; 1772 + 15.	20
ALGARVES, Kingdom of,	Africa,	1772 + 16.	17
ALGERIA,		1846, rain of ashes off the coast of; 1856, extended in a transverse direction to the mountains along the north shore of the Mediterranean; 1866 + 1; 1867, centre at Mouzzaia; 1869 + 3; 1873; 1874 + 2 N.–S.; 1875.	14

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ALGIERS,		1541 : 1715 + 3 ; 1716 + 12 ; 1717 ; 1722 + 2 ; 1724, extended from Milianah to Bona ; 1773 + 20 ; 1792 ; *1802* + 6, felt on board a ship fifty miles at sea, also on the Spanish coast, a village swallowed up : *1807* + 8 ; 1825 + 10, and country in a line N.E.–S.W., + 5 ; 1833 + 1 ; 1839 ; 1841 + 1 ; 1842 + 2 + 1 W.–E. + 3 ; 1843 + 4 ; 1845 + 2 + 1 S.–N. ; 1846 + 4 ; 1847 ; 1848 N.–S. ; 1850 + 6 ; 1851 + 1 ; 1852 E.–W. + 1 E.S.E.–W.N.W. ; 1853 ; 1854 + 1 ; 1855 + 2 N.–S. ; 1856 + 3 ; 1857 ; 1858 E.–W. + 1 ; 1859 W.N.W.–E.S.E. + 1 ; 1860 ; 1863 + 1 N.–S. ; 1865 + 5 + 4 N.–S. ; 1866, extended N.–S. to Bouffarick, Blidah, Boghar ; 1867 N.W.–S.E. + 13, centre of intensity at villages of Mouzzaiaville, La Chiffa, El Affroun, Ameer-el-ain, and Bon-Roumir ; 1869 + 1 S.S.E–N.N.W. ; 1870 ; (1874 + 1) N.–S. + 4 ; 1876.	168
ALQUEZ,	Pyrenees,	1843 + 1.	2
ALHAMA,	Murcia,	1855 + 9 ; 1856 + 4 ; 1864.	16
ALIANO,	Basilicata, Italy,	1857.	1
ALICANTE,	Spain,	1747 ; 1823 + 6 ; 1845 ; 1853 ; 1861 ; 1863 N.E.–S.W + 1 ; 1874 E.–W. + 1.	15
ALKAN TURTOVSKY,	Stanitz of, Caucasus,	1861 + 1 ; 1862.	3
ALLAN,	Drôme (?) France,	1873.	1
ALLAUCH,	Bouches du Rhône,	1873.	1
ALLEMONT,	Isère,	(1839 + 3) N.E.–S.W. + 1.	5
ALLENJOIE,	Doubs,	1857.	1
ALLERUP VILLAGE,	Jutland,	1873.	1
ALLESSANDRIA,	Piedmont,	1828 + 1, limits: Marseilles, and a curve joining Vercelli, Voghera, and Genoa ; 1855 ; 1881 + 1 ; 1882 + 1.	7
ALLEVARD,	Isère,	1784 ; (1855 + 2) S.S.W.–N.N.W. ; 1881.	5
ALLIER, Department,	France,	1879.	1
ALLUES,	Savoy,	1855 ; 1865.	2
ALMBY,	Gothland,	1847.	1
ALMERIA,	Andalucia, Spain,	1804 S.–N. + 7 ; 1851 + 1 ; 1853 ; 1856 ; 1858 + 1 ; 1860 + 3 + 2 S.E.–N.E. ; 1863 + 1, followed course of the Almanzora from mouth to Seron, 70–80 km. ; (1882 + 2) S.E–N.W. ; 1883.	28
ALMERIA, Province,	Spain,	1882 S.E.–N.W. + 8.	9
ALMISSA,	Dalmatia,	1843.	1
ALNWICK,	Northumberland,	1782.	1
ALMORADE,	Murcia, Spain,	1829 + 10 ; 1833 + 2.	14
ALOUPOCHORI,	Messenia Prov., Greece,	1846.	1
ALPS, THE,		1590 ; 1755 + 1 ; 1756.	4
ALPS, Northern Side of,		1876.	1
ALPS, Southern Side of,		1882.	1
ALSACE,		1357 ; 1571 ; 1682 + 3 ; 1728 ; 1755 ; 1757 ; (1784 + 3) S.W.–N.E. ; (1829 + 3) N.–S.	17
ALSANZ,	Bavaria, S.-W. Germany,	1869 + 5.	6

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ALSEUG, . . . near	Blidah, Algeria, . . .	1873.	1
ALSHEIM, . . .	Darmstadt, ...	1869 + 2.	3
ALSH, ...	W. Coast of Rosshire, . .	1878.	1
ALSO-RAKOS, . . .	Transylvania, ...	1868 W.–E.	1
ALSO-NESSENIEZ, . .	Marmaros Com., Hungary, .	1880 N.E.–S.W.	1
ALSO-DAMBOIN, . .	Croatia, ...	1880.	1
ALSUTH, ...	Hungary, ...	1870.	1
ALSWEILER, . . .	St. Wendel C., Rh. Prussia,	1869.	1
ALSTÄTTEN, Alstatten,	Dusseldorf C., Rh. Prussia, .		
ALSTÖTTEN, . . .	Switzerland, . . .	1720.	1
ALTAMORA, . . .	Terra de Barri, . . .	1784 + 3 ; 1845.	5
ALTAUSSEE, . . .	Styria, ...	1446 + 2 ; 1870 + 1.	5
ALTBREISACH, . .	Baden, ...	1882.	1
ALTENBERG, . . .	Bohemia, ...	1756 + 1 ; 1862 S.–N.	3
ALTDORF, . . .	Uri C., Switzerland, . .	1774 + 7 ; 1856 ; 1861 ; 1862 ; 1868, felt also at Sienna and Castel Gondolfo, + 1 W.–E. + 1 ; 1869 + 3 ; 1879.	19
ALTEA, ...	Valencia, Spain, . . .	1861 + 1.	2
ALTENSTEIG, . . .	Lr. Austria, . . .	1822.	1
ALTENDORF, . . .	Moravia, ...	1840.	1
ALTEMARKT, . . near	Laas, Illyria, . . .	1870.	1
ALTENRATH, . . .	Rhine Valley, . . .	1869.	1
ALTENAHR, . . .	Rhenish Prussia, . .	(1869 + 1) W.–E.	2
ALTENSTAIG, . .	Wurtemberg, . . .	(1855 + 2) W.–E.	3
ALTENKIRCHEN, . .	Rhenish Prussia, . . .	(1869 + 1) S.–N. + 2.	4
ALTENBACH, . . .	Odenwald, ...	1872.	1
ALTENBURG, . . .	Transylvania, . . .	1873.	1
ALTENBERG, . . near	Mur Zuschlag, Styria, . .	1881.	1
ALTGRADISCA, . .	Sclavonia, ...	(1854 + 1) S.S.W.–N.N.E.	2
ALTHASEN, . . .	Austria, ...	1857.	1
ALTHEIM, . . .	Black Forest, Würtemberg, .	1869 + 1.	2
ALTI-AGASH, . . .	Caucasus, ...	1869.	1
ALTKIRCH, . . .	Alsace, ...	1837 + 1 ; 1875 S.–N.	3
ALTLAAK, . . near	Gotschee, Carniola, . .	1870.	1
ALTNAU, ...	Thurgovia, ...	1840.	1
ALTOGGENBURG, . .	St. Gall C., Switzerland, .	1849 + 2.	3
ALTRINGHAM, . .	Chester, England, . .	1750.	1
ALTREU, ...	Solothorn C., . . .	1846.	1
ALTSTŒLTEN, . .	St. Gall C., . . .	1864.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ALTSOHL, . . .	Schemnitz, Hungary, . .	1862.	1
ALTSZOERY, . . .	Comorn Com., Hungary, .	1866.	1
ALVENEU, . . .	Lr. Engadine, . . .	1880 + 1, extended distance of about 10 km.	2
ALVES or OLVES, Prov.,	Iceland, ...	1370.	1
ALVITO, ...	Terra di Lavoro, . . .	1873 + 3.	4
ALTZEY, ...	Darmstadt, ...	1869 + 4.	5
ALZHANC, . . .	Illyria, ...	1770.	1
ALZIRA, ...	Spain, ...	1747.	1
AMAGER, ...	Danemark, ...	1829.	1
AMALFI, ...	Principato C., Italy, . .	1687 ; 1875.	2
AMALREA, . . .	Scotland, ...	1819.	1
AMANTEA, . . .	Calabria, ...	1868 ; 1870 ; 1871 + 2.	5
AMASIA, ...	Asia Minor, . . .	1870 ; 1871.	2
AMATRICE, . . .	Abruzzo Ult., . . .	1859.	1
AMBAR, ...	El Tezerah, Asiatic Turkey,	1139.	1
AMBÉRIEUX, . . .	Ain, France, . . .	1770 ; 1851 ; 1881.	3
AMÉLIE-LES-BAINS, .	Pyrenees Orient., France, .	1862.	1
AMERSFORT, . . .	Utrecht, ...	1756.	1
AMEUR-EL-AIN, . .	Algeria, ...	1867.	1
AMÖNEBURG, . . .	Cassel, S.W. Germany, .	1869 + 1.	2
AMPEZZO, . . .	Venetia, ...	1881.	1
AMSTERDAM, . . .	. . . . .	1756 ; 1765 + 2 ; 1761.	5
AMPHISSA, . . .	Corinth G., Greece, . .	1870, town destroyed, + 5 ; 1871 + 4.	11
ANAIS, ...	Charente, France, . .	1864 + 1.	2
ANAPA, ...	Black Sea, ...	1834.	1
ANATOLIA, . . .	. . . . .	1874 ; 1862 ; 1863 + 1.	4
ANAZIN, ...	Messenia Prov., Greece, .	1846.	1
ANCA, ...	Portugal, ...	1857.	1
ANCONA, ...	. . . . .	1667 + 3 ; 1672 ; 1691 + 3 ; 1752 ; **1756 + 3** ; 1760 + 3 ; 1766 + 3 ; 1790 + 5 ; 1803 ; 1813 + 1 ; 1818 + 1 ; 1822 ; 1828 ; 1829 + 1 ; 1837 ; 1849 + 1 ; 1853 ; 1856 ; 1864 N.N.E.–S.S.W. ; 1865 + 3 N.N.E.–S.S.W. + 1 W.E. ; 1867 + 2 S.W.–N.E. ; 1868 N.–S. + 1 N.W.–S.E. ; 1869 + 1 ; 1870 W.–E. + 1 W.–E. + 3 ; 1873 ; 1875 ; 1878 + 11.	76
ANDALUCIA, . . .	Spain, ...	**1504** ; 1755 ; *1860.*	3
ANDAUX, ...	B. Pyrenees, . . .	1855.	1
ANDE, ...	E. Pyrenees, . . .	1824.	1
ANDERMATT, . . .	Uri C., ...	1880 + 3.	4
ANDERNACH, . . .	Rhenish Prussia, . . .	1869 S.–N. + 3 ; 1878 + 1.	6
ANDEZ, ...	Lr. Engadine, . . .	1882.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ANDREJWSKAIA, . .	Caucasus, ...	(1830 + 8) N.–S.	9
ANDRIA, ...	Bari prov., ...	1851.	1
ANDRUVISTA, . .	Peloponnesus, . . .	1860.	1
ANDUTZ, ...	Croatia, ...	1880.	1
ANET, ...	Berne, ...	1777.	1
ANGERMANNLAND, Prov.	Sweden, ...	1752 + 1.	2
ANGERVILLE, . . near	Hâvre, ...	1833.	1
ANGHIARI, . . .	Arrezzo, Italy, . . .	1781.	1
ANGLE ISLAND, . near	Malta, ...	1661.	1
ANGERS, ...	Maine and Loire, . .	584; 1083; 1106; 1522; 1524; 1750; 1822; 1836 + 3; 1867; 1869 E.–W.	13
ANGLESEA ISLAND, .	Wales, ...	1780; 1782; 1827; 1842; 1874.	5
ANGLET, ...	B. Pyrenees, . . .	1858.	1
ANGOULÊME, . . .	Charente, ...	(1817 + 1) N.–S.; 1864 + 1; 1866 E.–W. + 1.	6
ANGORA, ...	Anatolia, ...	(1856 + 2) E.–W.	3
ANGURI, ...	Anatolia, ...	1857.	1
ANHAUSEN, . . .	Oldenburg, Germany, . .	1869 + 1, the shocks stronger in the neighbourhood of the Basalts.	2
ANNABERG, . . .	Saxon Voigtland, . .	1811; 1821; 1824; 1862 + 1.	5
ANNALUNGA, . . .	Sienna, ...	1851.	1
ANNECY, ...	Savoy, ...	1322; 1839 + 7; 1840; 1841; *1844 + 1*; 1847; 1855 S.E.–N.W.; 1881.	16
ANNEVILLE, . . .	Eure, ...	1863.	1
ANNONAY, . . .	Ardèche, ...	1740 + 2.	3
ANRAS, ...	Tyrol, ...	1848.	1
ANREJO, ...	Spain, ...	1817.	1
ANSBACH, . . .	Bavaria, ...	1855, 1869.	2
ANSE, ...	Rhône, ...	1841.	1
ANSLA, ...	Gothland, ...	1847.	1
ANSPACH = ANSBACH, .	Bavaria, ...	1774; 1787.	2
ANSTO, ...	Norway, ...	1757 + 1.	2
ANTAS, ...	Andalucia, ...	1863 + 5.	6
ATEQUERA, . . .	Malaga Prov., Spain, . .	1852.	1
ANTIBES, . . .	Alpes Maretimes, France, .	1808; (1818 + 3) S.E.–N.W.; 1854, extended along the coast simultaneously from Genoa to Anatolia.	6
ANTIOCH, . . .	Asia Minor, ...	458; 525; *528 + 3*; 557; 579; 587 + 1; 639; 775; *859*, 1500 houses destroyed; 1092; 1109, the earth opened and houses were swallowed up; 1114 + 1, Trialoth, Maniscum, Manistria, and other towns destroyed wholly or in part; 1155; *1158*, twenty thousand lives lost in Syria; 1183; 1212; 1823 + 3; 1872 + 3, one-third town destroyed.	30
ANTWERP, . . .	. . . . .	1395; *1640*; 1671; 1692; 1760 + 1; 1803.	7

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
AOSTA,	Italy,	1851; 1856; 1857; 1858; 1867 S.–N. + 1; 1871; 1880; 1881 + 1.	10
AOSTA, VALLEY OF,		1881.	1
APAMEIA = Kŭlat-el-Mudik,	Syria,	A.D. 50–53.	1
APPENZELL, Canton,		1881.	1
APPENZELL,		1720; 1755; 1817; 1827; 1835; 1852; 1877; 1881.	8
APRICA,	Lombardy,	1882 W.–E.	1
APRICENA,	Capitanata,	1851; 1852.	2
APRIGLIANO,	Calabria,	1870 + 1.	2
APT,	Vaucluse,	1812; 1843.	2
APTHORPE,		1844.	1
AQUAPENDENTE, near	Rome,	1755.	1
AQUI,	Piedmont,	1808.	1
AQUILA,	Abruzzo,	1461 + 1 + **3**; *1672*, extended in a N.–S. line from Monte-reale to Amatrice—this line nearly the same as that of Pontecorvo, of 1654; 1691; 1703 + 4, extended from Rome to Naples and Aquila, in a line N. by W.—S. by E. along the Appennines, + 1; 1704, extended over same country as in the previous year, + 2 + 160; 1706; 1730; 1762; 1786 + 42; 1791 + 3; 1805; 1809 + 20; 1825 + 7; 1826 + 3; 1827 + 1; (1828 + 1) S.E.–N.W.; 1842; 1848 + 1; 1850; 1851 + 3; 1857 + 2; 1859 + 2; 1870; 1881 + 3.	283
AQUILA,	Spain,	1762.	1
AQUITAINE,		1208.	1
ARABIA,		550; 631; 640; 742; 856; 1122.	6
ARAD,	Hungary,	1879.	1
ARAGON, Prov.,	Spain,	1373 + 1; **1431**; 1817.	4
ARAHOVA,	Corinth G., Greece,	1870.	1
ARAL,	Russia,	1802.	1
ARANJUEZ,	Spain,	1761; 1804.	2
ARANYOS,	Schüt Island, Danube,	1877 + 1.	2
ARARAT MOUNTAIN,	District of, Armenia,	1319; **1840 + 10**, numerous fissures opened, all parallel to the rivers Araxes and Arpatchai, the fissures seen to open and shut every moment in accordance with the motion of the earth; great number of vertical explosions from the bottom of holes like little craters, cast up immense quantities of water and sand.	12
ARBOIS,	Jura, France,	1841.	1
ARBOLEAS,	Andalucia, Spain,	1863 + 2.	3
ARBON,	Thurgau,	1666; 1881.	2
ARCACHON,	Gironde,	(1854 + 1) N.–S.; 1866 S.S.E.–N.N.W.	3
ARCHANGEL, Gov.,	Russia,	1829 + 1.	2
ARCHIPELAGO,	Greece,	1491; 1508 + 3; 1570; 1829 + 1; 1856; 1867 + 7; 1869 + 2.	20

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ARCHIPELAGO, Coast of,	Greece,	1855 + 1.	2
ARCO,	Tyrol,	1879.	1
ARCOLA,	Spezia, Italy,	1853.	1
ARDBRA,	Sweden,	1853 s.-n. + 1.	2
ARDES,	Puy de Dôme,	1806; 1808.	2
ARDEZ,	Engadine,	1860 + 2.	3
ARDÈCHE, Department,		1873.	1
ARDÉBIL,	Azerbaidschan, Persia,	*1864* + 9.	10
ARDAGAN or ARDAHAN,	On the Kour, Armenia,	1868.	1
ARDENNES, Fort of,	Luxembourg,	1878.	1
ARDEA,	Rome, Italy,	1855.	1
ARDICHETTO,	Etna,	1880.	1
ARDVOIRLICH,	Scotland,	1826; 1831.	2
ARENA DI TAGGIA,	Apulia, Italy,	1874 + 3.	4
ARDON,	Valais, C.,	1882.	1
ARDUS,	Grisons, C.,	1878.	1
ARENA,	Calabria,	1869.	1
ARENDAL,	Nedennes, Norway,	1844 + 5; 1845.	7
ARENDSEE, The,	Saxony,	823; 829.	2
ARENSBERG,	Strelitz, Germany,	1756.	1
AREOPOLIS,	Ætylos, Greece,	1867 + 2.	3
AREZZO,	Italy,	1339; 1781; 1796; 1810 + 1; 1823; 1854; 1869.	8
ARGENCES,	Normandy,	1878.	1
ARGENTA, near	Ferrara,	1624.	1
ARGENTINE,	Maurienne, Savoy,	1847; 1849.	2
ARGÈLES,	Hautes Pyrenees,	1821; 1850 + 9; 1854 s.e.-n.w. + 3; 1855 n.e.-s.w. 1868.	17
ARGOS,	Greece,	*1784 + 3.*	4
ARGOSTOLI,	Chephalonia Islands,	1866 + 21; 1867 + 65.	88
ARGYLE, Coast of,		1871.	1
ARGYLESHIRE,		1880 + 3.	4
ARGYROCASTRO,	Albania,	1858 + 1; 1860 + 5.	8
ARHAMÆDE ISLAND,	Caspian Sea,	1876 + 5.	6
ARIANO,	Principato, Italy,	1733; 1794; 1853.	3
ARKANGELSK, / ARCHANGELSK,	Kherson, S.W. Russia,	1847.	1
ARLBERG,	Tyrol,	1881.	1
ARLANC,	Puy de Dôme,	1880.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ARLES, ...	Bouches du Rhône, . .	1678 + 2 ; 1781 + 3 ; 1868.	8
ARLESHEIM, . . .	Bâle C., Switzerland, . .	(1836 + 1) S.–N.	2
ARLINGTON, . . .	. . . . .	1179.	1
ARMAGH, ...	. . . . .	1880.	1
ARMAIOLO, . . near	Sienna, Italy, . . .	1859.	1
ARMENIA, . . .	. . . . .	1754 ; 1871 + 10.	12
ARMENTO, . . .	Basilicata, ...	1857.	1
ARMITAGE, . . .	. . . . .	1583.	1
ARMLEY, ...	. . . . .	1871.	1
ARMSIDE VILLAGE, .	. . . . .	1789.	1
ARNEY, ...	Côte d'Or, ...	1802.	1
ARNEDO, ...	Old Castille, Spain, . .	1817.	1
ARNEDILLO, . . .	,, ,, ,, . .	1817.	1
ARNES-SYSSEL, . .	Iceland, ...	1786.	1
ARNOLDSTEIN, . .	Carinthia, ...	1855 S.E.–N.W. + 3.	4
ARNSBERG, . . .	Westphalia, . . .	1878.	1
ARNŒSS, District, . .	Norway, ...	1854.	1
AROK-SZALLAS, . .	Hungary, ...	1868 + 13.	14
ARONA, ...	Novara, Italy, . . .	1870.	1
ARONAT, ...	Puy de Dôme, . . .	1877.	1
ARPINO, ...	Terra di Lavoro, Italy, .	1870.	1
ARRA, ...	Pontevedra, . . .	1853 W.–E.	1
ARREAU, ...	Hautes Pyrenees, . .	(1859 + 1) W.–E.	2
ARRICIA OR RICCIA, .	Campagna, ...	1855 ; 1869 + 1.	3
ARRAN ISLANDS, . .	. . . . .	1826.	1
ARRIÈGE, Department, .	. . . . .	1837.	1
,, Mountains of, .	. . . . .	1870 + 4.	5
ARTA, ...	Albania, Turkey, . .	1858.	1
ARTENA, ...	Romagna, ...	1881.	1
ARTH, ...	Schwytz C., . . .	(1850 + 4) E.–W.	5
ARUDI, ...	Basses Pyrenees, . .	1773 + 5.	6
ARUNDEL, . . .	. . . . .	1734.	1
ARYS, ...	Johannesberg C., Prussia, .	(1861 + 1) N.E.–S.W.	2
ARZENGAN = ARZENJAN,	Sivas Paschelic, Durighi Dis., [Asia Minor,	1255, terrible shocks for three days—direction S.–N., many thousand people perished.	6
ARZEW, ...	Algeria, ...	1858 ; 1872 ; (1873 + 1) E.–W.	4
ARZILLA, ...	Algeria, ...	1755.	1
ARZL, ...	Tyrol, ...	(1881 + 1) E.–W.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ASBACH, ...	Neuwied C., Prussia, . .	1869.	1
ASCA, ...	Pesth Com., Hungary, .	1863.	1
ASCALON, . . .	Palestine, ...	1032.	1
ASCH, ...	Bohemia, ...	1872.	1
ASCHAFFENBURG, .	Bavaria, ...	1728 ; 1855 ; 1869 + 1 ; 1871 + 11.	16
ASCIANO, . . .	Tuscany, ...	1849 E.–W. ; 1850 S.–N. ; 1851.	3
ASCOLI, ...	Calabria, Capitanata, . .	1720 ; 1851 ; 1855 + 1 ; 1880.	5
ASCOLI-PICENO, . .	Central Italy, . . .	*1361*, four thousand people perished ; 1851 S.–N.	2
ASELLA, ...	Basilicata, ...	1851.	1
ASHBURG, . . .	. . . . .	1771.	1
ASHFORD, . . .	Kent, ...	1580 ; 1776 ; 1814.	3
ASHTON, ...	. . . . .	1871.	1
ASHTON-ON-RIBBLE, .	. . . . .	1871.	1
ASIA MINOR, . . .	. . . . .	B.C. 12 ; A.D. 17 + 1 ; 358 ; 458 ; 471 ; 494 ; 740, continued at intervals for eleven months ; 1064 ; 1114 ; 1204 ; 1667 + 3 ; *1754* ; 1796, a most destructive earthquake, especially at Latakiah = Laodicea, + 2 ; 1870 ; 1871 ; 1872 ; 1875, centre at sources of Meander river ; 1881 ; 1882.	25
ASINALUNGA, . . .	Tuscany, ...	(1849 + 5) E.–W. ; 1854 + 1.	8
ASKERSUND, . . .	Sweden, ...	1816.	1
ASKHALZYHD, . .	N. Lat. 41° 39′, Long. 40° 39′ Koutais, Gov. Russia, .	1848 ; 1858.	2
ASLAN-AGA, . . .	Messenia Prov., Greece, .	1846.	1
ASOLANO, District, .	Treviso, ...	1695.	1
ASOLO, ...	Venetia, ...	1861 + 9.	10
ASOPUS, R., . . .	Greece, ...	1853.	1
ASPATRIA, . . near	Carlisle, ...	1871.	1
ASPATH, ST., . . .	. . . . .	1782.	1
ASPRAMONTE, . .	Calabria, ...	1881.	1
ASPREMONT, . . .	Hauts, Saône, . . .	1862 + 1.	2
ASPROCHOMATOS, . .	Messenia Prov., Greece, .	1846.	1
ASSISI, ...	Perugia, ...	1832 + 1 ; 1854 + 4.	7
ASTI, ...	Piedmont, ...	1703 + 2 ; 1753 ; 1828 + 1 ; 1866 ; (1878 + 1) E.–W.	9
ASTRACAN, . . .	. . . . .	1830 + 1.	2
ASSMANSHAUSEN, . .	Nassau, ...	1869 + 1.	2
ASUANO, ...	Sienna, ...	1854.	1
ASZOD, ...	Hungary, ...	1868 + 1.	2
ATALANTE MOUNTAINS,	Greece, ...	B.C. 425 ; A.D. 1853.	2
ATH, ...	Hainaut, Belgium, . .	1828.	1
ATENA, ...	Principato Cit., Italy, .	*1857 + 5* ; 1873.	7

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ATHENS, ...	Greece, ...	B.C. 426; A.D. 1818; 1835 + 2, simultaneously at Thebes; 1840; 1841 + 11 E.–W. + 2; 1842 + 2; 1844 + 1; 1852 + 6; 1853 N.–S. + 12; 1854 + 5, the shocks always followed the line of Athens, Calcis, Thebes, and Talanto; 1855 + 1; 1856; 1858 S.E.–N.W. + 1; 1859 + 5; 1860 + 5; 1861; 1862 S.W.–N.E.; 1864 + 2; 1865 + 6; 1866 + 7; 1867 + 7; 1868 + 1 N.–S. + 4; 1869 + 1 + 1 N.W.–S.E.; 1870 + 4; 1873; 1874; 1876 + 3 W.–E., extended to Corinth, Eubea, Volo, and Cephalonia; 1879 + 4, centre at Xylocastron, near Corinth.	121
ATELLA, ...	Basilicata, ...	1855 + 3.	4
ATTICA, Prov., . .	Greece, ...	1853; 1854; 1861.	3
ATZBACH, . . .	Lahn Valley, . . .	1869 + 3.	4
ATZENBRUCK, . .	Lower Austria, . . .	1875.	1
AUBONNE, . . .	Vaud Cant., . . .	1829 + 3.	4
AUCH, ...	Gers, ...	1854; 1855 + 1; 1862; 1870 + 1.	6
AUEN, ...	Glaris C., ...	1868; 1869; 1871.	3
AUERBACH, . . .	Saxon Voigtland, . .	1862 S.W.–N.E.; 1875.	2
AUERBACH, . . .	Odenwald, Bavaria, . .	1869 + 3; 1873 + 2; 1874.	8
AUGSBURG, . . .	Bavaria, ...	1572; 1670; 1689 + 1; 1755; 1756; 1769; 1771, extended over a surface of sixty leagues by forty along the Rhine; 1778; 1787; 1819; 1826; 1873, extended—N., Augsburg; S., Umbria; E., Carlstadt; W., Berne.	13
AUGUSTA, . . .	Catania, Sicily, . . .	1848 + 1, the pier sank, leaving fifty fathoms of water, + 3.	5
AULENDORF, . .	Wurtemberg, . . .	1855 + 2.	3
AULETTA, . . .	Abruzzo Cit., . . .	*1857 + 5*; 1867 + 2.	9
AULT, Canton, . . .	Normandy, ...	1882.	1
AUMALE, ...	Algeria, ...	1858. Mount Dorah split and a lake formed, + 1, extended to Algiers, + 1; 1860; 1861 + 3 N.–S.; 1863 + 6 + 1 S.–N. + 2 N.–S. + 10; 1866; 1867 + 3 + 1; 1869.	35
AURELIA, . . .	Roman States, Italy, . .	1753.	1
AURIS, ...	Isère, ...	(1839 + 3) N.E.–S.W.	4
AUSSEE, ...	Styria, ...	1871 + 1.	2
AUSSERBERG, . near	Viège, Valais C., . .	1855.	1
AUSTREZAT, . . .	Puy de Dôme, . . .	1880 E.–W.	1
AUSTRIA, . . .	. . . . .	1556 + 1; 1588; *1601*; 1615; 1620; 1690; 1876;	8
,, Northern, .	. . . . .	1868.	1
,, Upper, . .	. . . . .	1869; 1876.	2
,, Lower, . .	. . . . .	1876.	1
AUSTUR, Jökull Volcano,	Iceland, ...	1827.	1
AUTUN, ...	Saône-and-Loire, . .	1784; 1802 + 3; 1855; 1871.	7
AUVERGNE, . . .	. . . . .	549; 1804; 1833 + 6; 1877.	10

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
AUXERRE, . . .	Yonne, ...	1682 ; 1799.	2
AUXONNE, . . .	Côte d'Or, ...	1855 ; 1863 + 2.	4
AUZAT, ...	Pyrenees, ...	1852.	1
AVANCHES, . . .	Vaud C., ...	1877.	1
AVANCHERS, . . .	Maurienne, Savoy, . .	1847.	1
AVEIRO, ...	Beira, Portugal, . . .	1752 ; 1857.	2
AVELLINO, . . .	Principato Ult., . . .	1720 ; 1787 ; 1805 ; 1826 ; 1846 ; 1853 + 7 ; 1856.	14
AVELLA, ...	,, ,, . . .	1852 + 1.	2
AVERSA, ...	Terra di Lavoro, . . .	1694 ; 1805.	2
AVÈSNES, . . .	Nord, ...	1828 E.–W. ; 1838.	2
AVESTE, ...	Kopperberg, Sweden, . .	1855.	1
AVESTRY, . . .	Shropshire, ...	1863.	1
AVEZZANO, . . .	Abruzzo, ...	1850 + 3.	4
AVIGLIANO, . . .	Basilicata, ...	1856.	1
AVIGLIANA, . . .	Susa, Italy, ...	1848.	1
AVIGNON, . . .	Vaucluse, ...	1678 + 2 ; 1693 ; 1763 ; *1769* S.–N. and N.–S. + 1 ; *1799* + 1 ; 1812 ; 1855 E.–W.	11
AVINTES, ...	Porto, Portugal, . . .	1863.	1
AVRANCHES, . . .	Manche, ...	1750.	1
AYHNO, ...	. . . . .	1731.	1
AYLAT, ...	Puy de Dôme, . . .	1863 + 2.	3
AYR, ...	. . . . .	1880.	1
AZCHUR, ...	Caucasus, ...	1868.	1
AZIZCH, ...	10 kms. S. of Ephesus, .	1866.	1
BABENHAUSIN, . .	Darmstadt, ...	1869 + 4.	5
BABYLON, . . .	. . . . .	1853.	1
BACAN, ...	Roumelia, ...	1880.	1
BACHARACH, . . .	Rhenish Prussia, . . .	1853 + 2 + 1 ; 1869 + 2 S.E.–N.W. + 1 ; 1872.	9
BACK-KALE, . . .	Armenia, ...	1871.	1
BAES-FÖLDVAR, . .	Servia, ...	1881.	1
BADAJOZ, . . .	Estremadura, . . .	1847.	1
BADALICAO, . . near	Genoa, ...	1851 + 1.	2
BAD EMS, . . .	Nassau, ...	1869.	1
BADEN, Duchy, . .	. . . . .	1830 ; 1837 ; 1841 ; 1851 ; 1859 ; 1862 + 2 ; 1863 ; 1869 ; 1871 ; 1880 + 2, two distinct districts of maximum effect—the smaller in the Hœrnisgrundas and by Herrenwies in the Schwartzwald ; the centre in the vicinity of Langoukandel.	14

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BADEN-BADEN, . .	S.W. Germany, . . .	1869 ; 1871.	2
BADEN, ...	Aargau, ...	1852 ; 1861 S.E.–N.W. ; 1881 + 2.	5
BADEN, ...	Lower Austria, . . .	1873 ; 1874.	2
BADENWEILER, . .	Baden, ...	1851.	1
BADEVIL, . . .	Doubs, ...	1857.	1
BAD LEUK, . . .	Valais, ...	1879 ; 1881.	2
BAD SODEN, . . .	Nassau, ...	1869 + 1.	2
BAD VELDIS, . . .	Carniola, ...	1880.	1
BAD KREUTH, . .	Bavaria, ...	1866 ; 1871.	2
BAGDAD, ...	. . . . .	1129 ; 1769 + 3, three thousand houses thrown down ; 1864 + 9 ; 1865 + 3 + 3 E.–W. ; 1867.	23
BAGNÈRES DE BIGORRE,	. . . . .	1835 ; 1843 ; 1848 ; 1850 S.E.–N.W. + 1 ; 1852 N.N.W.–S.S.E. + 1 ; 1854 + 8 ; 1867 + 1 ; 1869 ; 1873 + 41 ; 1874 + 4 ; 1875 + 2 W.–E. + 5 ; 1876 ; 1877.	76
BAGNÈRES DE LUCHON,	. . . . .	1784 + 3 ; 1843 ; 1847 E.–W. ; 1851 N.–S. ; 1852 E.–W. + 2 + 1 N.–S. + 1 ; 1855 + 1 E.–W. + 2 ; 1865 ; 1869.	18
BAGNEVILLE, CANTON, .	Dieppe Arondissement, .	1845.	1
BAGNARA, . . .	Calabria, ...	1852.	1
BAGNOL, ...	Pay de Dôme, . . .	1863.	1
BAGNOLI, . . .	Principato Ult., . . .	1853.	1
BAGNO-REALE, . BAGNOREA, . .	Viterbo, ...	1695 ; 1881.	2
BAGNI DE ST. GULIANO,	Pisa, ...	1846 ; 1850 ; 1851 + 1.	4
BAGLA-AGHATCH, . .	84 miles from Macri, Anatolia,	1855.	1
BAIGORRY, . . .	Basses Pyrenees, . . .	1858 ; 1860 + 1.	3
BAIKAL LAKE, . .	Siberia, ...	(1862 + 33) N.W.–S.E., repeated shocks, sinking of ground on the right bank of the Selenga river; extended to Irkutsch ; fissures produced with projection of water and flame ; the principal fissure E.–W. + 5, 1863.	40
BAINS DE GOURNIGEL,	Berne, Switzerland, . .	1855 E.–W.	1
BAINS DE LAVAY . .	Vaud C., ...	1851 + 3.	4
BAIREUTH, . . .	Bavaria, ...	1853 + 2.	3
BAKO, ...	Zala-Csapi Com., Hungary,	1848 + 3 ; 1858 ; 1860 N.–S.	6
BAKU, ...	Derbend, Transcaucasia, .	1830 (fifteen versts W. of) ; 1861 ; 1867 ; 1868.	4
BAKLIKI, ...	15 vests W. of Baku, . .	1838.	1
BALDUINSTEIN, . .	Presidence of Weisbaden, [Hesse,	1869 S.W.–N.E.	1
BÂLE, CANTON, . . .	. . . . .	1721 ; 1755 ; 1856 ; 1877 + 1.	5
BALAQUER, . . .	Cataluñia, ...	1855.	1
BALEARIC ISLANDS, .	. . . . .	1851 ; 1852.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BÂLE, ...	. . . . .	856, chasms opened in many places; 1021; 1062; 1346; **1348**; 1355; 1357; 1372; 1415 + 1; 1428; 1444; 1470; **1492**; 1498; 1514; 1522; 1523 + 2; 1524; 1529; 1531; **1533** + 4; 1537; 1538 + 3; 1540; 1548; 1552; *1565 + 2*; 1569; 1571; 1574; 1576 + 2; 1577 + 8; 1591; 1601; 1604; 1610; 1612; 1614 + 4; 1621 + 3; 1630 + 1; 1644; 1647; 1650 + 23; 1651 + 3; **1652**; 1653 + 1; 1656 + 2; 1657; 1661 + 4; 1668; 1669; 1672; 1674; 1679; 1680 + 4; 1681; 1682; 1683; 1684 + 1; 1691 + 2; 1711; 1721 E.–W. + 1; 1728; 1729; 1731; 1736; 1737 + 2; 1743 + 1; 1755; 1757 + 1; 1764; 1770 + 1: 1774; 1784; 1786; 1787; 1788; 1790; 1792; 1796; 1806; 1817; 1823; (1830 + 3) S.W.–N.E.; 1835; 1836 S.–N. + 1; 1837 + 1; 1842; 1843; 1847; 1851 + 1; 1855 + 3; (1856 + 3) N.W.–S.E. + 1 + 3 N.W.–S.E.; 1863 S.–N. + 1; 1864; 1870 + 1 + 1 S.W.–N.E. + 2; 1871 + 1 S.W.–N.E.; 1878 + 2; 1879 + 2; 1880 + 1; 1881 + 4.	208
BALIKASNI = BALIKESIR,	Anatolia, ...	1870 W.–E. + 9.	10
BALINGEN, . . .	Würtemberg, . . .	(1830 + 2) W.–E.; 1855; 1875.	5
BALKAN MOUNTAINS, .	S.W. part of, . . .	1879.	1
BALLAHULISH, . .	Argyle, ...	1880.	1
BALLEN COAN, . .	Glentyon, ...	1818.	1
BALLYMOE, . . near	Tuam, Ireland, . . .	1756.	1
BALLIAGA, . . .	Messenia, Greece, . .	1846.	1
BALLASSA-GYARMARTH,	Hungary, ...	1851; 1852.	2
BALMÉ D'ALA, . .	Savoy, ...	1881.	1
BALMONT, . . .	Savoy, ...	1770.	1
BALNACARA, . . .	Ross County, Scotland, .	1878.	1
BALTIC, NORTH COAST OF,	. . . . .	1822.	1
BALVANO, . . .	Basilicata, ...	1857; 1858.	2
BALZANNO, . . .	Terra di Lavoro, . . .	1858.	1
BAMBERG, . . .	Bavaria, ...	1860; 1872.	2
BAMBRIDGE, . . .	. . . . .	1871.	1
BANBURY, . . .	. . . . .	1731.	1
BANCA, ...	Basses Pyrenees, . . .	1860 + 1.	2
BANCO, ...	Frosinone, ...	1880.	1
BANAT KOMLOS, . .	Servian Worwod, . .	1879 + 1.	2
BANDA, ...	Switzerland, . . .	1855.	1
BANJALOKA, . . .	Carniola, ...	(1880 + 2) N.E.–S.W.	3
BANGOR, ...	Carnarvon, Wales, . .	1782; 1818; 1852.	3
BANLOCK, . . .	Hungary, ...	1858 + 1.	2
BANOVA = BANNIJE, .	Sillein Com., Hungary, .	1858 + 4.	5
BANNAT, ...	. . . . .	1790; 1802; 1838 + 3.	6
BAR, ...	Bouche du Rhône, . .	1854.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BARANELLO,	Molise, Italy,	1857 + 1.	2
BARANO,	Ischia Islands,	1881.	1
BARANYA Com.,	Hungary,	1880.	1
BARATOS,	Transylvania,	1861 N.W.–S.E.	1
BARBASTRO,	Aragon, Spain,	1856.	1
BARBERINO di Mugello,	Tuscany,	1864 + 12.	13
BARCELLOS,	Minho, Portugal,	1756.	1
BARCELONA,	Spain,	1224; 1703; 1771 E.–W. + 3; 1817; 1845 N.–S. 1852; 1853; (1855 + 2) N.W.–S.E.; 1868; 1870.	15
BARCELONETTA,	Basses Alps,	1844 + 1; 1872.	3
BARCZAS, near	Kaschan, Hungary,	1858.	1
BARCS,	Hungary,	1880.	1
BARDI,	Tuscany,	1802; 1835.	2
BARDONÈCHE,	Susa, Italy,	1881.	1
BARDJI BOU ARRERIDJI,	Constantine Prov., Algeria,	1864 + 5; (1867 + 1) W.–E.	8
BARDSEY ISLAND,	Carnarvon, Wales,	1831.	1
BARGA,	Tuscany,	1740 + 3; 1746 + 10.	15
BARGI,	Cuneo, Piedmont,	1808 + 81; (1878 + 1) E.–W.	84
BARGSCHLOSS,	Baden,	1841.	1
BARI,	Italy,	1267; 1844 S.E.–N.W. + 1; 1845; 1851; 1856 + 1; 1858.	8
BARILE,	Basilicata,	*1851*, town entirely destroyed, + 3; 1852 + 2; 1855 + 3; 1875.	12
BARJAC,	Gard,	(1840 + 2) N.W.–S.E.	3
BAR-LE-DUC,	Meuse,	1682.	1
BARLETTA,	Terra de Barri,	1720; 1851; 1856; 1858.	4
BARMEN,	Solengen C., Westphalia,	1869; (1881 + 1) S.W.–N.E.	3
BARNSTAPLE,	. . . . .	1789.	1
BARNAGE,	Staffordshire,	1852.	1
BARNMOUTH,	Merionetshire,	1820.	1
BARONAL,	Calabria,	1707.	1
BARRA,	. . . . .	1880.	1
BARRA HEAD,	. . . . .	1880.	1
BARREAUX,	Hautes Alpes,	1784.	1
BARRÈGES (BARÈGES),	Hautes Pyrenees,	1784; 1789 + 1; 1854 + 10; 1869 S.–N.	15
BARRINSTEIN,	Bohemia,	1756.	1
BARTBERG,	Upper Austria,	1869 + 2.	3
BAS,	Allier,	1859 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BASILICATA, LA, . .	. . . . .	1666 ; *1683* + 1 ; *1688* + 3 ; 1694 ; 1733 ; 1826 N.–S. + 2 ; 1845 + 3 ; **1851**, disastrous ; **1857**, extended to Reggio, in south : Brindisi in east : Vasto, in north : Terracina and Naples, in west : centre at Montemurro, 12,500 lives lost, + 8—the second shock nearly destroyed Montemurro, Saponera, Viggiano, Tito, S. Angelo, Marisio, Paterno, Tramutola, Castel Saraceno, Calvello, Potenza, Polla, Pertosa, Anlitta, Montesano ; 1858 + 6 + 14 ; 1859 + 3 ; 1860 ; 1874.	53
BASALA, ...	South Spain, . . .	1356.	1
BASSANO, . . .	Vicenza, Italy, . . .	1822 ; 1836 + 2.	4
BASSORAH, . . .	Turkey in Asia, . . .	1864 ; 1865 + 1.	3
BASTA, ...	Messenia Prov., Greece, .	1846.	1
BASTIA, ...	Ombria, ...	1854 + 4.	5
BASSES PYRENEES, Department, ...		(1858 + 2) S.W.–N.E.	3
BATH, ...	. . . . .	1248 ; 1750 ; 1775 ; 1868.	4
BATNA, ...	Algeria, ...	1856 + 4 + 1 E.–W. ; 1858 N.W.–S.E. ; 1866 + 2 ; 1867 ; 1869 N.W.–S.E. + 10.	22
BATTAGLIA, . . .	Padua, ...	1873.	1
BATYRSCHI KUBUROI, .	Belibei Dist., Caucasus, .	1867, R = 20 versts.	1
BAUMHOLDER, . .	Rhenish Prussia, . . .	1869.	1
BAUSHEIM, . . .	. . . . .	1870 + 1.	2
BAVARIA, . . .	. . . . .	786 ; 1021 ; 1212 ; 1329 ; 1348 ; 1556 + 3 ; *1601* ; 1755 ; 1812 ; 1820 ; 1847, part of ; 1860.	15
,, Lower, . .	. . . . .	1858.	1
,, . . .	Palatinate, ...	1880 + 2.	3
BAYEUX, ...	Calvados, ...	1750.	1
BAYON, ...	Gironde, ...	1852.	1
BAYONNE, . . .	. . . . .	1761 ; 1763 + 1 ; 1807 ; 1817 ; 1843 ; 1847 ; 1857 ; 1858 S.W.–N.E. ; 1868 ; 1875 W.–E.	11
BAZIAS, ...	Croatia, ...	1879.	1
BEARN, ...	Pyrenees, ...	1618 ; 1772 ; 1782.	3
BEAS DE SEGURA, .	Lamancha, Spain, . .	1829.	1
BEATENBERG, . .	. . . . .	1880, extended over distance of 24 km.	1
BEAUCAIRE, . . .	Gard, ...	1836.	1
BEAUCOURT, . . .	Montbelliard, Doubs, . .	1852 ; 1857 ; 1858.	3
BEAUFORT, . . .	Maurienne, Savoy, . .	1847 ; 1855 ; 1863 + 1.	4
BEAUJEU, . . .	Rhône, ...	1841 ; 1846.	2
BEAUMONT D'APT, .	Vaucluse, ...	1812 + 6 ; 1835 + 1.	9
BEAUMONT LEPERTHES,	,, ...	1852 + 3.	4
BEAUME LES DAMES, .	Doubs, ...	1774.	1
BEAUMORRIS, . .	. . . . .	1780.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BEAUMONT, . . .	Drôme, ...	1856 + 1.	2
BEAUNE, ...	Côte d'Or, ...	1855 ; (1882 + 1) S.–N.	3
BEAUPRÉAU, . . .	Maine et Loire, . . .	1858 S.–N.	1
BEAUVAIS, ...	Oise, ...	1756 + 1 ; 1802.	3
BECHBURG, . . .	9 miles E. of Soleure, . .	1853.	1
BECHERBACH, . .	Nahethale (?) . . .	1869.	1
BECLE'S PARISH, . .	England, ...	1657.	1
BECKRATH, . . near	Gladbach, ...	1881.	1
BECK, ...	Netherlands, . . .	1828.	1
BEDARRIDES, . . .	Vaucluse, ...	1769.	1
BEDARRIEUX, . .	Hérault, ...	1867 + 1.	2
BEDFORD, . . .	Suffolk, England, . .	1690 ; 1792 ; 1863.	3
BEDBURG, . . .	Rhenish Prussia, . . .	1868.	1
BEDONIA, ...	Tuscany, ...	1835.	1
BEDOUS, ...	Basque Prov., . . .	1843.	1
BEEDENKIRCHEN, .	Odenwald, ...	1873.	1
BEESTON, . . near	Nottingham, . . .	(1865 + 2) N.–S.	3
BÈGLES, ...	Gironde, ...	1854.	1
BEHOBIE, . . .	Basses Pyrenees, . . .	1854 N.–S.	1
BEJA, ...	Alentijo, Portugal, . .	1791.	1
BEKES, ...	Gran Com., Hungary, . .	1852 + 4 ; 1859 W.–E. + 1 ; 1866 + 4.	12
BELAPH, ...	Switzerland, . . .	1880.	1
BELCKINGTON, . .	. . . . .	1660.	1
BELEM, . . . near	Lisbon, ...	1756 ; 1858 ; 1878;	3
BELFAST, . . .	. . . . .	1843 ; 1880.	2
BELFORT, . . .	Haut Rhin, . . .	1774 + 2 ; 1818 ; (1829 + 3) N.–S ; 1855 + 2 ; 1877 ; 1881.	13
BELGIUM, . . .	. . . . .	1504 ; 1505 ; 1554 + 5 ; 1580 ; *1640 + 2* ; 1756 + 2 ; 1828 + 1 ; 1865 ; 1881, extended into Rhenish Prussia and Westphalia.	19
BELGRADE, . . .	. . . . .	1669 ; 1689 ; 1763 ; 1773 + 2 ; 1808 + 2 ; 1879 N.–S.	10
BELLA, ...	Basilicata, ...	1857 ; 1858, continuous, + 2 N.–S. + 2.	6
BELLENAVES, . .	Allier, ...	(1857 + 1) S.E.–N.W.	2
BELLE-ISLE, . . .	Morbihan, . , . .	1860 N.W.–S.E.	1
BELLEGARDE, . .	. . . . .	1851.	1
BELLIZONA, . . .	Tessin Cant., . . .	1513 ; 1638 ; 1832 ; 1853 ; 1868 W.–N.W. ; 1882.	6
BELLUNA OR BELLUNO,	Venetia, ...	1771 + 3 ; 1866 + 3 ; 1873, extended to N. Italy and to Germany, + 10 + 1 + 85 + 1 N.W.–S.E. + 1 ; 1874 + 6 ; 1875 + 1 ; 1881 + 3.	120

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BELLEY, ...	Ain, ...	1770 E.–W. + 1 ; 1822 + 1 ; (1823 + 1) E.–W. ; 1829 ; 1838 ; 1840 ; (1841 + 1) N.–S.	11
BELMONTE, . . .	. . . . .	1855.	1
BELPASSO, . . .	Etna,.	1842 ; 1849 ; 1850.	3
BELJASNWAR, . .	Caucasus, ...	1868 + 1 N.–S.	2
BELSCHITZA MINI, .	Border of Carniola and [Carintbia,	1879.	1
BENDER, ...	Bessarabia, ...	1790 ; 1826 ; 1838 + 3.	6
BENDORF, . . .	Coblentz C., Rhen. Prussia,	1869 W.–E. + 3.	4
BENI-FERAH, . . .	Biskra Dis., Algeria, . .	1869 + 1.	2
BENEVENTUM, . BENEVENTO, . .	Principato Ult., . . .	847 ; 982 ; 990 ; 1125 + 14 ; 1139 ; 1702 ; 1733 + 2 ; 1739 ; 1782 + 1 ; 1794 ; 1805.	28
BENIMCHI, . . .	Alicante Prov., Spain, .	1856 + 2.	3
BENI-SOUK, . . .	Biskra Dis., Algeria, . .	1869 + 1.	2
BENIGANIM, . . .	Valencia, Spain, . . .	1803.	1
BENJANIANI, . . .	Caucasus, ...	1853.	1
BENNWEL, . . near	Bâle, ...	1881.	1
BENSHEIM, . . .	Odenwald, Darmstadt, . .	1871 + 3 ; 1872 + 2 ; 1873 + 2 S.W.–N.E. general direction of shocks.	10
BENISANET, . . .	Cataluñia, Spain, . .	1845 + 2.	3
BEON VILLAGE, . .	Pyrenees, ...	1777 E.S.E–W.N.W. ; 1778.	2
BERAT, ...	Albania, ...	1851 ; 1860 + 1 ; 1863 ; 1865.	5
BERATI, ...	Thessaly, ...	1850.	1
BERBER, ...	Bosnia, ...	1880.	1
BERCETTO, . . .	Parma, Italy, . . .	1832 ; 1856 E.–W.	2
BERDICSZEW, . .	Podolia, ...	1790.	1
BERG, ...	Carinthia, ...	1869.	1
BERGAMO, . . .	Italy, ...	1786 ; 1851 ; 1882.	3
BERGELL, . . .	Grisons, ...	1871.	1
BERGEN, ...	Norway, ...	1612 ; 1632 ; 1649 ; 1773 ; 1774 + 3 ; 1779 ; 1782 ; 1821 N.–S. + 3 ; 1823 ; (1824 + 1) S.W.–N.E. ; 1834 N.W.–S.E. + 1 ; 1847 + 1 S.W.–N.E. + 2 ; (1855 + 1) E.–W. ; 1863 ; 1865 ; 1866 ; 1870 N.–S.	29
BERGEN-OP-ZOOM, .	N. Brabant, Netherlands, .	1711 + 3.	4
BERGEN, . . between	Hanau and Frankfort, . .	1779.	1
BERGERAC, . . .	Dordogne, France, . .	1862 N.–S.	1
BERGHEIM, . . .	Vosges, ...	1843 ; 1868 + 1.	3
BERGHEIM, . . .	Rhenish Prussia, . . .	1878.	1
BERGISH-GLADBACH, .	Mulheim C., Rhen. Prussia,	1869.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BERGSTRASSE, between	Eberstadt and Heidelberg, [Hesse,	1871 + 7 ; 1873 + 1 ; 1877 ; (1882 + 1) N.E.–S.W.	13
BERGÜN, ...	Grisons, ...	1880 + 5.	6
BERGSKIRKA, . . .	Sweden, ...	1858.	1
BERJA, ...	Almeria Prov., . . .	1863 + 1.	2
BERKSHIRE, . . .	. . . . .	1683.	1
BERKUM, . . .	Bonn C., ...	1869.	1
BERLIN, ...	. . . . .	1828 ; 1839 + 1 ; 1872.	4
BERNAU, ...	Schwartzwald, . . .	1879 S.W.–N.E.	1
BERNDORF, . . .	Vienna, ...	1873 ; 1874.	2
BERNE, ...	. . . . .	1356 ; 1569 ; 1650 + 1 ; 1667 + 3 ; 1726 ; 1728 ; 1729 ; 1774 ; 1784 ; 1802 + 4 ; 1808 ; 1809 ; 1817 ; 1820 ; 1821 ; 1822 ; 1827 ; 1829 ; 1830 ; 1837 + 2 ; 1839 ; 1840 ; 1841 ; (1847 + 1) N.–S. ; 1851 + 1 ; (1852 + 1) S.E.–N.W. ; 1854 N.–S. + 1 ; 1855 + 3 ; 1856 S.W.–N.E. + 2 ; 1857 ; 1858 E.–W. + 2 ; 1873 ; 1879 ; 1880 + 4 ; 1881 S.W.–N.E. 27th January—Limits : Geneva, Morges, Payenne, Freiburg in Uri, Biel, Thur, Lucerne, Muotthal, Glarus, St. Gallien, Herisau, Frauenfeld, Schaffhausen, Neustadt in Schwartzwald, Mulhousen, + 18 + 1 S.E.–N.W. + 1 W.–E.	80
BERNE Canton, . .	. . . . .	1620 ; 1650 + 1 ; 1652 + 3 ; 1663 ; 1721 ; 1877 ; 1879 ; 1880.	12
BERNESE, Oberland, .	. . . . .	1839 N.W.–S.E. + 1.	2
BERNEK, ...	Black Forest, Würtemberg, .	1789 + 1.	2
BERNHARDEN, . .	Grisons, ...	1865.	1
BERNKASTEL, . .	Westphalia, . . .	1869 + 2.	3
BERTINORO, . . .	Forli Dis., ...	1870 + 3 ; 1881.	4
BERZITA, . . near	Tirano, Albania, . . .	1860 + 1 S.–N.	2
BERZIGHELLA, . .	Ravenna, ...	1780 + 10.	11
BERZENCZE, . . .	Hungary, ...	1857.	1
BESANÇON, . . .	. . . . .	1755 + 1 ; 1774 ; 1783 ; 1784 ; *1831* + 1, at the same time at Freibourg, Switzerland ; 1843 N.–S. 1851 ; 1855 ; 1862 ; 1865.	12
BESSARABIA, . . .	. . . . .	1832 + 1 ; 1838 + 3 ; 1843 ; 1879 ; 1880 S.W.–N.E. + 1, the surface shaken in Russia limited by a line running N.–S. from Odessa to Swenigorod, and thence S.W. by Uman and Bjelzy.	10
BESSAS, ...	Gard, ...	1840 N.W.–S.E. + 2.	3
BESSES, ...	Puy de Dôme, . . .	1863.	1
BESSUNGEN, . . .	Darmstadt, ...	1872.	1
BETHANCOURT SUR MER,	Normandy, ...	1882 N.W.–S.E.	1
BETHARRAM, . . near	Pau, Pyrenees, . . .	1850 ; 1863 + 5.	7
BETPONEY, . . .	Hautes Pyrenees, . .	1784.	1
BETTOLA, . . .	Parma, ...	1849.	1
BETTONA, . . .	Perugia, ...	1854.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BETTSCHWANDEN, .	Glarus, C., ...	1701.	1
BETLEY, ...	. . . . .	1863.	1
BETZA, ...	Asia Minor, . . .	1869.	1
BETZDORF, . . .	Altenkirchen C., R. Prussia,	1869.	1
BEUGGEN, . . .	Baden, ...	1878.	1
BEVAGNA, . . .	Perugia, ...	1835 + 5.	6
BEVERS, ...	Upper Engadine, . . .	1826 + 18; 1827 + 1; *1864* + 1; 1871 N.–S. + 1 + 1 N.W.–S.E.; 1882 N.W.–S.E.	26
BEX, ...	Vaud C., ...	1712; 1754; 1812; 1842 + 1; 1846, Mr. Merian has pointed out that the line from Bex to Yverden, coincides approximately with the direction of the coast of Tuscany—the ordinary direction shocks at Bex; 1851; 1853; 1854 + 12; 1855 + 18 (the shocks felt at Bex since 1813 have always had a direction N.N.W.–S.S.E.); 1862; 1868; 1874; 1879 + 1; 1881 + 6; 1882.	53
BEYNES, ...	Basses Alpes, . . .	1863.	1
BEYRUTH, . . .	Palestine, ...	A.D. 560: **1836**; 1849; 1850; 1855; 1856 + 2 E.–W.; 1859; 1863; (1870 + 1) W.–E.; 1872.	14
BEZIERS, ...	Hérault, ...	1745.	1
BIALYSTOCK, . . .	S. W. Russia, . . .	*1803* W.– . + 3.	4
BIANCARILLA, . .	Sicily, ...	1849; 1850.	2
BIARRITZ, . . .	Basses Pyrenees, . . .	1841, and all along the S.W. coast of France from Boucan to Hendaye (B. Pyrenees).	1
BIAVUTZ, . . .	,, . . .	1858.	1
BIBERACH, . . .	Würtemberg, . . .	1832; 1842 S.W.–N.E. + 1 N.E.–S.W. + 5; 1846.	9
BIBEREST, . . .	Solothurn C., . . .	1853.	1
BIBERSBERG, . . .	Little Carpathians, . .	1866.	1
BIBLIS, ...	Darmstadt, . . .	1869 + 3; 1871 + 29; 1873 E.–W.	35
BIBONA.	Tuscany, ...	1846 + 1; 1871.	3
BIEBESHEIM, . . .	Hesse, ...	1869 + 8.	9
BIEBRICH, . . .	Nassau, ...	1858; 1869.	2
BIEL OR BIENNE, . .	Berne C., ...	1796 S.–N. + 1; 1881.	3
BIEL, ...	Valais, ...	1879. 1881.	2
BIELLA, ...	Oropa Mountains, Lombardy,	1807 N.E.–S.W.; 1851; 1881 + 1.	4
BIELITZ, ...	Gallicia, ...	1786 + 1; 1855 N.–S.	3
BIELEFELD, . . .	Westphalia, . . .	1612.	1
BIELO-KEUTSCH, . near	Tiflis, Caucasus, . . .	1860 E.–W.; 1867 S.–N.; 1870 + 1; 1871 + 1.	6
BIENNE OR BIEL (*see* BIEL),			
BIERINGEN, . . .	Würtemberg, . . .	1881.	1
BITRAR-ZSADANG, .	Hungary, ...	1870.	1
BIKKE, ...	Bosnia, ...	1862.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BIKOL, ...	Gran Com., Hungary, . .	(1860 + 2) E.–W. ; 1861 + 2.	6
BILEK = BILETCHI (?)	Adriatic, ...	1880 N.–S.	1
BILEK = BELETCHI (?)	Bosnia, ...	1882 W.–E.	1
BILK, ...	Dusseldorf, ...	1869.	1
BILLIGHEIM, . . .	Bavaria, ...	1880.	1
BILLOM, ...	Puy de Dôme, . . .	1881.	1
BIMOCZ, ...	Presburg C., Hungary, .	1870.	1
BINGERBRÜCK, . .	Creuznach C., Rh. Prussia,	1869.	1
BINGEN, ...	Darmstadt, ...	1869 + 4.	5
BINOSCO, ...	Maggia Valley, Ticino C., .	1868 + 1.	2
BIONATZ, . . .	Piedmont, ...	1880 S.–N.	1
BIOT, ...	Haute Savoie, . . .	1865.	1
BIRKENAU, . . .	Darmstadt, Odenwald, . .	1873.	1
BIRMINGHAM, . .	. . . . .	1777.	1
BISACCIA, . . .	Basilicata, ...	1851.	1
BISCAY, ...	. . . . .	1817.	1
BISCEGLIE, . . .	Terra de Barri, . . .	1858.	1
BISCHOFFSHEIM, . .	Baden, ...	1869 + 9.	10
BISCHOFLAAK, . .	Carniola, ...	1874 ; 1879 + 2.	4
BISCHOFWERDA, . .	Thurengerwald, Saxony, .	1855.	1
BISCHOFWERDER, .	Austria, ...	1768 ; 1855.	2
BISCHWEILER, . .	Bas Rhin, ...	1805 + 1.	2
BISERTA (AN UTICA), .	Algeria, ...	408 to 410.	1
BISCHOFSTEINITZ, .	Bohemia, ...	1858.	1
BISHOPTHORPE, . .	Yorkshire, England, . .	1754.	1
BISKRA, ...	Constantine Prov., Algeria, .	(1861 + 3) S.E.–N.W. + 3 ; 1867 ½ N.E.–S.W. ; (1869 + 5) N.E.–S.W.	14
BISOKA, ...	Croatia, ...	1881.	1
BISTHAM (Mallet's Report, p. 262.)	Switzerland, . . .	1836.	1
BITCHE, ...	Moselle, ...	1846.	1
BITONTO, . . .	Terra de Barri, . . .	1806.	1
BITSCHITSH, . . .	Hungary, ...	1858.	1
BITHYNIA, . . .	. . . . .	33 ; 358 ; 447.	3
BITZITZA, . . .	Sillein C., Hungary, . .	1858 + 50.	51
BITINJE, ...	Istria, ...	1870 + 1.	2
BJELOI-KLEUTSCH, .	Caucasus (*see* Bielo-Keutsch).		
BJASTA-BO, . . .	Natro Parish, Sweden, .	1847.	1
BJELZY, ...	Bessarabia, ...	1880.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BLACK FOREST, . .	Würtemberg, . . .	1787 ; 1863.	2
,, S.W. part of,	. . . . .	1878 ; 1879 S.W.–N.E.	2
,, S. part of, .	. . . . .	1881 + 2.	3
BLACKMORE, . . .	. . . . .	1583.	1
BLACK SEA, E. Shore of,	. . . . .	1840.	1
,, W. of Caucasus,	. . . . .	1870.	1
BLACKPOOL, . . .	. . . . .	1835.	1
,, N.E. Coast of,	. . . . .	1870.	1
BLACKBOURNE, . .	. . . . .	1869.	1
BLAIRATHOL, . . .	Perthshire, . . .	1880.	1
BLANZY, ...	Saône et Loire, . . .	1855.	1
BLATNA, ...	Bohemia, ...	1872.	1
BLAY, ...	Savoy, ...	1852.	1
BLEANAVON MTS., .	. . . . .	1868.	1
BLAZEDOOTE, . near	Agram, Croatia, . . .	1881 + 25.	26
BLEENBACH, . . .	Berne C., ...	1845.	1
BLEIBERG OR BLEIBOURG,	Carinthia, ...	1837 ; 1844 ; 1855 ; 1865 + 3 ; 1866 + 1 ; 1867 N.E.–S.W. + 4 ; 1879 + 2 ; 1881 ; 1882.	19
BLEIKASTEL, . . .	Rhenish Prussia, . . .	1869.	1
BLEISTADT, . . .	Bohemia, ...	1824 + 1.	2
BLESLE, ...	Haute Loire, . . .	1806 ; 1808.	2
BLIGNY SUR OUCHE, .	Côte d'Or, ...	1841 + 2.	3
BLIDAH, ...	Algeria, ...	1802 + 3 ; 1825 + 10, the places shaken lay in a line directed N.E.–S.W., or from Algiers to the Canary Is. ; 1842 ; 1847 ; 1854 ; 1855 S.–N. ; 1858 + 2, felt at same time at Milianah, Boufarick, and Cherchel ; (1862 + 2) N.W.–S.E. ; 1865 + 2 ; 1866 ; 1867 E.–W. + 259 + 3 W.–E. + 1 ; 1869 ; 1870 ; 1871 ; 1873 + 1 N.–S. + 1 ; 1874 ; 1875 ; 1876 + 1.	303
BLŒKZYL, . . .	Holland, ...	1843.	1
BLOIS, ...	Loire et Cher, . . .	1678.	1
BLOXHAM, . . .	. . . . .	1731.	1
BLUDENZ. . . .	Tyrol, ...	1875 N.–S.	1
BOA, ...	North Italy, . . .	(1878 + 1) E.–W.	2
BOARGUS, . . .	Turkey, ...	1871.	1
BOBBIO, ...	Sardinia, Italy, . . .	1808 ; 1824 + 1 ; 1882 N.–S. + 6.	10
BOBLINGEN, . . .	Würtemberg, . . .	1855 ; 1879.	2
BOBORAK, . . .	Hungary, ...	1860.	1
BOCINO, ...	. . . . .	1461 + 1 ; 1465.	3
BOCKENHEIM, . .	Hesse, Nassau, . . .	1869 + 2.	3
BOCKSTEIN, . . .	Gastein V., Saltzbourg, .	1845 N.W.–S.E.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BOCHUM, . . .	Westphalia, . . .	1881 + 1.	2
BÖDELI von Interlaken,	. . . . .	1880.	1
BODENHEIM, . . .	Darmstadt, ...	1869 + 12.	13
BODENBACH, . . .	Bohemia, ...	1872.	1
BODENSEE, . . .	. . . . .	1874.	1
BODENDORF, . . .	Upper Austria, . . .	1868 + 1; 1869 + 1.	4
BODMIN, ...	. . . . .	1757.	1
BODOE, ...	Scandinavia, . . .	1866.	1
BOË, ...	Norway, ...	1834.	1
BŒOTIA, ...	. . . . .	B.C. 426.	1
BOFFINGEN, . . .	Gaildorf Dis., Würtemberg,	1861.	1
BOGHAR, ...	Algeria, ...	1853 S.S.E.–N.N.W. + 10; 1863 + 7; 1865; 1866; 1867 E.–W. + 3.	25
BOGNOR, ...	. . . . .	1824; 1834.	2
BOHEMIA, ...	. . . . .	1230; 1326; 1329; 1443; 1590; *1601*; 1615; 1690; 1786; 1833; 1860; 1876.	12
BOJANO, ...	Molise, Italy, . . .	1805; 1850 + 2 N.–S. + 2.	6
BOIS LE DUC, . .	Brabant, Netherlands, . .	1804; (1843 + 1) E.–W.	3
BOJIE-PROMSYL, . .	10 versts from mouth of Kur river, left bank, Caucasus,	1861.	1
BOLADORE, . . .	. . . . .	1851.	1
BOLECHO, . . .	Silesia, ...	1785.	1
BOLI, ...	Anatolia, ...	1863 + 3.	4
BOLLÈNE, . . .	Vaucluse, ...	1873 + 1.	2
BOLLFUSS, . . .	Denmark, ...	1882.	1
BOLOGNA, . . .	. . . . .	1173; 1222; 1349; 1365 + 2; 1393; 1433; 1455 + 2; 1465; 1495; 1505 + 1; 1666; 1667 + 3; 1671; 1695; 1704; 1719 + 3; 1762 + 3; 1779 E.–W. + 8 + 2 E.–W. + 2; 1780; 1781 + 1; 1786; (1801 + 2) N.E.–S.W.; 1828; 1834; 1844 + 2; 1850 + 1 S.E.–N.W.; 1854; 1856 E.–W.; 1857 E.–W. + 2 N.E.–S.W. + 2; 1858 + 1; 1859 S.E.–N.W.; 1861 + 1; 1865 E.–W. + 1 S.E.–N.W. + 1 S.S.E.–N.N.W. + 1 E.–W.; 1864 + 1 + 1 S.W.–N.E.; 1867 E.–W.; (1869 + 2) N.N.W.–S.S.W. + 1; 1870 E.–W.; 1874; 1880 + 19 N.–S. + 6 + 1 S.W.–N.E.; 1881, extended to Verona and to Florence, + 1 N.W.–S.E. + 1 + 1 S.–N, extended to Padua and to Venice, + 9 + 1 N.W.–S.E. + 1 W.–E. + 2 E.–W. + 2 S.E.–N.W.	130
BOLSENA, . . .	Viterbo, ...	1783 + 1.	2
BOLSENA LAKE, . .	,, ...	1881 + 1; 1882 + 4.	7
BOLTIGEN, . . .	Berne C., ...	1816.	1
BOMMEL, . . .	Holland, ...	1843.	1
BONAMIS, . . .	Frankfort, S.W. Germany, .	1869.	1
BONDO, ...	Grisons, ...	1880 + 2; 1882.	4
BONDEVILLE, . . near	Fécamp, ...	1847.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BONE,	Algeria,	1850 E.–W.; 1856 + 2; 1859; 1866 + 1; 1867 + 1; 1870.	10
BONGIARDO,	Etna,	1880 + 11; 1881.	13
BONN,	Rhenish Prussia,	1755; 1756 + 2; 1762 + 5; 1786 + 1 + 3 + 3 + 1; 1812 + 1; 1828 + 2; (1846 + 4) S.E.–N.W.; 1852; 1868 + 1; 1869 N.N.W.–S.S.E. + 2 + 1 S.W.–N.E. + 1, extended along the Middle Rhine, + 6; 1871 + 2; 1873; 1874; 1878 + 1; 1881.	51
BONNDORF,	Schwartzwald, Baden,	1870.	1
BONNEVILLE,	Savoy,	1857 + 3.	4
BÖNNEGHEIM,	Würtemberg,	1861 + 1.	2
BÖNSTADT,	Nassau,	1869 + 1.	2
BONVILLARD,	Savoy,	1849.	1
BOPPARD,	Rhenish Prassia,	1619; 1780 S.–N.; 1846; 1869 + 6 + 2 W.–E.	12
BORDEAUX,		1580; 1660; 1743; 1750, and 12 leagues to west of; *1759* S.W.–N.E. + 1; 1761; 1778[a]; 1798; 1799; 1852 + 1 N.N.W–S.S.E.; 1854 N.–S.; (1855 + 1) E.–W.; 1867 N.W.–S.E. + 2; 1870, also at Tarbes, Auch, Tolosa, and Barcelona.	19
BORJAM,	Armenia,	1878.	1
BORMIO,	Sondrio, Italy,	1871.	1
BORNHOLM ISLANDS,	Baltic,	1600.	1
BORSCHAM,	Caucasus,	1868.	1
BORSŒ, Defiles of,	Szamos, Hungary,	1846.	1
BOSANA,	Croatia,	1853 + 2.	3
BOSCO-REALE,		1847.	1
BOPEL,	Savoy,	1855; 1865 + 1.	3
BOSELY,		1712.	1
BOSHJI-WODY,	Caucasus,	1870.	1
BOSNIA (Turkish),		1823.	1
BOSOWAND,	Caucasus,	1869.	1
BOSPHORUS,		1855 + 2; 1857; 1858; 1859 + 3; 1862; 1866; 1878 + 20.	32
BOTHNIA, Coast of,		1755.	1
,, Gulf of,		1869.	1
BOTZEN,	Tyrol,	1862 + 2; 1873 + 4 + 1 N.W.–S.E.	9
BOUDRUM,	Anatolia,	1856.	1
BOUDRUM,	Rhodes Island,	1860 W.–E.	1
BOUCAU,	Basses Pyrenees,	1841.	1
BOUFARRICK,	Algeria,	1858 + 2; 1859 E.–W.; 1865 + 2; 1866; 1867 + 3; 1870.	13
BOUGIE,	Algeria,	1856 + 9; 1860. 1863 N.–S.; 1864 N.–S. + 1; (1865 + 2) N.W.–S.E.	17
BOUILLARD,	Côte d'Or,	1882 S.–N.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BOUILLON, . . .	Luxembourg, Belgium, .	1767.	1
BOULAY, ...	Meurtha, ...	1846.	1
BOULOGNE-SUR-MER, .	. . . . .	1580 ; 1858.	2
BOUNYE, ...	Nantes Arondissement, .	1862 N.W.–S.E.	1
BOURBONNE LES BAINS,	Haute Marne, . . .	1780 N.–S. ; 1855 ; 1860 ; 1861 the Communes of Bourbonne, Villars, St. Marcelin, Fresnes, and Chattillon the most shaken ; surface shaken = 330 km. q., + 1 + 4 E.–W. + 37 ; 1862 ; 1863 a shock probable every two or three years.	48
BOURBON VENDÉE, .	. . . . .	1822.	1
BOURG EN BRESSE, .	Ain, ...	1755 + 1 ; 1770 E.–W. + 1 ; 1784 ; 1822 ; 1855 S.E.–N.W. + 2 ; 1857.	10
BOURGES, . . .	Cher, ...	1841 + 2 ; 1857 N.E.–S.W.	4
BOURG, ...	Gironde, ...	1852.	1
BOURG MADAME, . .	Pyrenees Orientales, .	1876.	1
BOURG ST. ANDEOL, .	Ardèche, ...	1873.	1
BOURG DUN, . . .	Seine Inférieure, . .	1835.	1
BOURGNEUF,. . .	Loire Inférieure, . .	1767.	1
BOURGET, . . .	Savoie, ...	1881.	1
BOUIN ISLAND, . .	La Vendée, . . .	(1799 + 1) S.W.–N.E.	2
BOURLEMENT, . near	Neuchateau, Vosges, . .	1784.	1
BOURNOI FORT, . .	Caucasus, ...	1830.	1
BOU-ROUMI, . . .	Algeria, ...	1867 + 6.	7
BOUSAADA, . . .	,, ...	1867 N.W.–S.E.	1
BOUVERET, . . .	Geneva Lake, . . .	1881.	1
BOVES, ...	Coni Province, Piedmont, .	1824 + 2 ; 1835 + 1.	5
BOVINO, ...	Basilicata, ...	1851 + 5.	6
BOWDEN, . . near	Manchester, . . .	1871 N.E.–S.W.	1
BOXBERG, . . .	Baden, S.W. Germany, .	1871.	1
BRA, ...	On the Stura, Italy, . .	1862 + 1 s. 40° W.–N: 40° E. ; 1869 ; 1878 E.–W.	4
BRABANT, . . .	. . . . .	1382 ; 1545 ; *1692* ; 1714 ; 1760 + 1 ; 1878.	7
BRACCIANO LAKE. .	Rome, ...	1781.	1
BRADLO, . . . near	Bezova, Hungary, . .	1874.	1
BRAGA, ...	Portugal, ...	1787 ; 1856 + 2.	4
BRAILA = IBRALA. .	Wallachia, ...	1844 ; 1862 ; 1881 E.–W.	3
BRAMBACH, . . .	Voigtland, Saxony, . .	(1840 + 3) N.W.–S.E. + 4.	8
BRAMSTEDT, . . .	Denmark, ...	1756.	1
BRANDENBOURG, . .	Margravate, Prussia, .	1638.	1
BRAND, ...	Voigtland, Saxony, . .	1862.	1
BRANIS, ...	Algeria, ...	1869.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BRANNOIS, . . .	Valais, ...	1882.	1
BRAUBACH, . . .	Nassau, ...	1869 + 5.	6
BRAUCH, . . .	Rhine Valley, . . .	1869.	1
BRAUNFILS, . . .	Rhenish Prussia, . .	1869 W.–E. + 2 W.–E. + 2.	5
BRAY, ...	Dublin, ...	1852.	1
BRAZZA ISLAND, . .	Dalmatia, ...	1870 + 1 ; (1881 + 1) S.W.–N.E.	4
BREAUTE, . . .	Goderville C., near Rouen, .	1881.	1
BREDA, ...	North Brabant, Netherlands,	1755 ; 1843 + 1.	3
BREGAZZO, . . .	Tyrol, ...	1851 + 6.	7
BREGENTZ, . . .	Vorarlberg, Austria, . .	1852 ; 1855 N.–S.	2
BREGENTZER WALD, .	,, ,, . .	1880.	1
BREITENBACH, . .	. . . . .	1780.	1
BREISACH, . . .	Baden, S. W. Germany, .	1823 ; 1837 E.–W. ; 1850 + 3.	6
BRENNER PASS, . .	Tyrol, ...	1878 W.–E. + 1.	2
BRENNETZ, . . .	Neuchatel Canton, . .	1878.	1
BRÈOS, ...	. . . . .	1843.	1
BRESCHIA, . . .	. . . . .	1060 ; 1223 : 1264 ; 1471 ; 1799 ; 1802 ; 1839 ; 1851 N.–S. ; 1880 + 2 ; 1882 + 3.	15
BRESLAU, . . .	Silesia, Prussia, . . .	1775 ; 1786 + 3 ; 1790 ; 1799 ; 1858 ; 1859 ; 1872.	10
BREST, ...	. . . . .	1753 ; 1776 ; 1810 ; 1820 ; 1834 ; 1849 + 1 ; 1851.	8
BRETEUIL, . . .	. . . . .	1756.	1
BRETIGNOLLES, . .	Indre et Loire, . . .	1772 + 1.	2
BRETTIGEN, . . .	Grisons, ...	1812 + 3.	4
BRIANÇON, . . .	Hautes Alpes, . . .	1766 ; 1784 + 2 ; 1785 + 1 ; 1808 E.–W. + 1.	8
BRIANZA, LA, . .	Lombardy, ...	1851.	1
BRIATICO, . . .	St. Euphemia, G. Calabria, .	1864 E.–W. ; 1865 + 12.	14
BRIENZA, . . .	Basilicata, ...	1857.	1
BRIDES, ...	Savoy, ...	1855 ; 1865.	2
BRIDGEWATER, . .	. . . . .	1839.	1
BRIDPORT, . . .	. . . . .	1750.	1
BRIDSTONE, . . near	Campsie, Scotland, . .	1845.	1
BRIEG, ...	Valais, ...	1754 S.–N. + 1 ; 1755 + 25 + 15 ; 1756 + 42 + 1 S.–N. ; 1786 ; 1826 ; 1837 + 3 ; 1850 + 1 ; 1855 ; 1856 + 1 ; 1857 + 1 ; 1869 ; 1880.	102
BRIEG, ...	Silesia, ...	1786 + 3.	4
BRIENTZ LAKE, . .	. . . . .	1729 ; 1880.	2
BRIGHTON, . . .	. . . . .	1553 ; 1859 ; 1863 ; 1865 ; 1878.	5
BRIGNASCO, . . .	. . . . .	1870 N.N.W.–S.S.E.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BRIGNOLES, . . .	Var, ...	1854 ; 1862 N.–S.	2
BRILL, ...	. . . . .	1666 ; 1683.	2
BRINDISI, . . .	. . . . .	1857 ; 1858 , 1881.	3
BRIOUDE, . . .	Haute Loire, . . .	1808 N.–S. + 1.	2
BRIQUERASQUE, . .	Piedmont, ...	1808 + 43.	44
BRISIGHELLA, . .	De Ravenna, . . .	1880 + 18 ; 1881 + 6 ; 1882.	27
BRISGAU, . . .	Baden, ...	1755 + 1.	2
BRISTOL, . . .	. . . . .	1574 ; 1752 ; 1775 ; 1795 ; 1839 ; 1852 + 1 ; 1868.	8
BRITTANY, . . .	. . . . .	1286 ; 1723 ; 1750, extended from Cherbourg to Avranches, and as far as Bayonne ; 1755 + 1 ; 1780 + 3.	9
BRIVES ALLUES, . .	Savoy, ...	1856.	1
BRIXEN, ...	Tyrol, ...	(1826 + 2) S.–N. ; 1862 + 1 ; 1869.	6
BROCHON, . . .	Côte d'Or, ...	1882 S.–N.	1
BROD, ...	Croatia, ...	(1881 + 1) E.–W.	2
BRODICK CASTLE, .	. . . . .	1880.	1
BRODENBACH, . .	St. Goar Dis., Rhen. Prussia,	1869 + 2.	3
BRUGES, ...	W. Flanders, Belgium, .	1828.	1
BRÜHL, ...	Cologne, C., Rhen. Prussia,	1869 + 1 ; 1878.	3
BRUGG, ...	Aargau Canton, . . .	1756 ; 1863 ; 1878 ; 1880.	4
BRUIDA, ...	Pelopenessus, . . .	1860 + 1.	2
BRUNDL, ...	S.E. of Fiume, Illyria, .	1870.	1
BRUNEBACH, . . .	Saxony, ...	1770.	1
BRÜNN, ...	Moravia, Austria, . .	1326 ; 1786 ; 1794 ; 1837.	4
BRUNNECK, . . .	Tyrol, ...	1862 + 2.	3
BRUNENDORF, . .	Carniola, ...	1865.	1
BRUNNSEE, . . .	Styria, ...	1880 + 1.	2
BRUNOTZ, . . near	Pistyan Neutra, Comorn., [Hungary.	1874.	1
BRUSIO, ...	Grisons, ...	1871 ; 1879.	2
BRUXELLES or Brussels,	. . . . .	1549 + 1 ; 1580 ; 1640 ; 1714 ; 1755 ; 1756 + 1 ; 1759 ; 1760 + 1 ; 1762 ; 1800 + 1 ; 1828 + 1 ; 1843 ; 1848 ; 1873 ; 1878 ; 1881 + 11.	32
BUARCOS, . . .	Portugal, ...	1752.	1
BUCCARI. . . .	Crotia, Austria, . . .	1776 ; 1838 + 2 ; 1853 ; 1870.	6
BUCHA, ...	Erzgebirge.. . . .	1552.	1
BUCHAREST. . . .	. . . . .	1787 + 3 ; 1802 ; (1813 + 2) N.W.–S.E. ; *1823* + 3 ; 1829 + 3 ; 1831 + 1 ; 1838 + 1 ; 1846 ; 1850 + 1 ; 1855 ; 1856 ; 1858 + 1 ; 1862 ; 1864 ; 1862 + 2 + 4 W.–E. + 1 N.–S. ; 1869 + 3 ; 1875 + 1 ; 1877 ; 1880 + 1 S.–N. ; 1882 + 3.	50
BUCHBERG, . . near	Glognitz, Lower Austria, .	1870 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BUCHOLTZ,	Schwartzwald,	1879.	1
BUDA (Pesth),		1763 + 1; 1783; 1786 + 1, extended from Upper Danube to Counties of Odenburg and Eisenburg.	5
BUDALIN,	Hungary,	1858.	1
BUDINGEN,	Hesse,	1869.	1
BUDESHEIM,	Darmstadt,	1869 + 2.	3
BUDISSEN,	Silesia,	1804 + 3.	4
BUDNA,	Dalmatia,	1880.	1
BUDUA,	9 miles S. of Cattaro,	1876; 1877; 1881.	3
BUDWEIS,	Bohemia,	1844; 1876; 1880 + 1.	4
BUES,	Schemnitz, Hungary,	1862.	1
BUEN CONVENTO,	Tuscany,	1848 N.–S.	1
BUG, near	Greifenberg, Silesia,	1879.	1
BUGLIANO (Buggiano)	Tuscany,	1740.	1
BUFLYAHAZA,	Hungary,	(1856 + 1) N.–S.	2
BUIR.	Rhine Province, Prussia,	1878 + 19 + 1 N.W.–S.E. + 1 S.–N. + 5, extended to the middle of Westphalia; 1879 S.–N. + 4; (1880 + 3) N.E.–S.W.	36
BUKENAU,	Odenwald,	1869.	1
BUKKARI,	Carinthia,	(1802 + 2) N.–S.; 1838 + 3 + *1*.	8
BUKOSNICA,	Krasso-Szoreny Com., [Hungary,	1881 N.–S.	1
BUKOVINA,	Galicia, Austria,	1875.	1
BULLA ISLAND,	Caspian Sea,	1857, the whole island was violently shaken, crevasses were opened, and from them rose columns of flame and a fluid matter (wlaga) which fell in drops of different sizes.	1
BULLÄRNISHÄRAD,	Scandinavia,	1859 S.W.–N.E.	1
BULLIS,		1860.	1
BULLY, near	Arbresle (Rhône),	1841.	1
BULTE, near	Hanover,	1805.	1
BUOL,	Rhine Province,	1822; 1856.	2
BURA,	Peloponnessus,	B.C. 373.	1
BURDER FORTRESS,	Bessarabia,	1843 N.–S.	1
BURDORF,		(1837 + 2) S.S.W.–N.N.E.	3
BÜREN,	Berne Canton,	1828; 1855; 1881 + 2.	5
BURFORD,		1683; 1731.	2
BURGUNDY,		1154; 1155; 1233; 1584; 1683 + 3.	8
BURG,	Prussia,	1824.	1
BÜRGEL.	Thuringia,	1685; 1869 + 2.	4
BURGBROHL,	Rhine Valley,	1869 + 3.	4

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
BURGOING, . . .	Isère, ...	1775.	1
BURGSCHLOSS, . .	Baden, ...	1841 + 1.	2
BURNABAD, . . .	Anatolia, ...	1880.	1
BURTON-ON-TRENT, .	. . . . .	1864.	1
BURTSCHIED (or Burschied)	Juliess C., Rhenish Prussia,	(1828 + 2) S.E.–N.W.; (1869 + 1) N.W.–S.E.	5
BURY, ...	. . . . .	1750; 1869 + 1.	2
BURY ST. EDMONDS, .	. . . . .	1863.	1
BUSCHOVEN, . . .	Rhine Valley, . . .	1869 + 1.	2
BUGUSH MOUNTAINS, .	North Persia, . . .	*1879 + 12*, 21 towns destroyed, 45 partially, 922 people killed.	13
BUSSERACH, . . .	Solothorn Canton, . .	1841 + 3.	4
BUSSY LE GRAND, .	Côte d'Or, ...	1866 E.–W. + 2.	3
BUTE COUNTY, . .	Scotland, ...	1880 + 3.	4
BUTTENHAUSEN, . .	Swabian Alps, . . .	1830.	1
BUTTELBORN, . .	Nassau, ...	1869 + 1.	2
BUTTERBACH, . .	Bohemia, ...	1824.	1
BUTT OF LEWIS, . .	. . . . .	1880.	1
BUTRUITO, . . .	Albania, ...	1866.	1
BUTZBACH, . . .	Darmstadt, ...	1733; (1869 + 2) E.–W.	4
BUZENÇAIS, . . .	Indre, ...	1841 + 1.	2
BUYUK-DÉRÉ, . .	Bosphorus, ...	1794; 1857.	2
BYALISTOCK, . . .	Poland, ...	1803.	1
BYGDEA, ...	Westerbotta, Sweden, . .	1747 S.W.–N.E.	1
CABELLA, . . .	Novi, Italy, . . .	1882.	1
CABO D'ISTRIA, . .	Illyria, ...	1870 + 2; 1881; 1882 + 2.	7
CABESTANY, . . .	Pyrenees Orientales, . .	1862.	1
CABO DEL COLLE, . near	Noria, ...	1859 + 2.	3
CABRERA ISLAND, .	Mediterranean, . . .	1851.	1
CADANJAC, . . .	Gironde, ...	1852.	1
CADEROUSSE, . .	Langedoc, ...	1840.	1
CADIZ, ...	. . . . .	1763, and simultaneously at Lisbon; 1772 + 1; 1773 + 2 E.–W.; 1778; 1822; 1852; 1858; 1879.	11
CAEN, ...	. . . . .	1755; 1799; 1829; 1847; 1849; 1853; 1878.	7
CAERMARTHEN, . .	. . . . .	1801; 1832; 1841.	3
CAGLI, ...	Urbino, ...	1753 + 4; 1781; 1843 + 7.	14
CAGLIARI, . . .	Sardinia Island, . . .	1618; 1771 + 3, and at the Islands of St. Peter, Tenedos, and Neutro, 1835 W.–E. + 1; 1855.	8

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CAGNANO, . . .	Capitinata, ...	1851 ; 1852 ; 1854.	3
CAGNES, ...	Alpes Maritimes, . .	1854 + 2.	3
CAGORI, ...	Epirus, ...	1860 + 5.	6
CAHORS, ...	Lot, ...	1807 ; 1808 ; 1854.	3
CAILLOT (? CAILLY), . near	Havre, ...	1833.	1
CAIRO, ...	Egypt, ...	1754 ; (1825 + 4) N.–S. ; 1844 + 1 ; 1845 + 3 ; 1846 + 2 E.–W. + 4 ; 1847 + 3 ; 1849 ; 1851 E.–W. ; (1856 + 2) E.S.E.–W.N.W. + 3 ; 1858 ; 1863 + 1 ; 1868 ; 1870 + 2.	38
CAIRNBAON, . . .	Scotland, ...	1880.	1
CAJETA, ...	Calabria Citra, . . .	1831.	1
CALABRIA CITRA, . .	. . . . .	*1835 + 13*, centre at Castiglione, which was utterly destroyed ; **1857** + 4, centre at Montemurro, Saponera, Viggiano ; also Tramutola, Marisco Vetere, Marisco Nuovo, Spinosa, Sarconi, Polla, Padula, Pertosa, Sassano, Montesano.	19
CALABRIAS, . . .	. . . . .	1169 ; 1184 ; 1186 ; 1454 ; 1538 + 20 ; 1544 + 2 ; 1549 ; *1596 + 2* ; **1599 + 2** ; 1602 + 3 ; **1614** ; **1619** ; 1624 ; 1626 + 2 + **1** + 15 + *1* + 5 ; **1638** + 3, extended along a line 25 geographical miles long from Reggio to Terra Novo S.W.–N.E. ; 1638 + 7 ; 1639 ; 1640 ; 1641 ; 1657 ; **1659**, from Pizzo to Mulato ; 1662 ; 1666 ; 1687 ; 1692 ; (**1693** + **1**) S.W.–N.E. ; 1694 ; 1697 ; 1706 + 1 ; 1707 ; 1720 + 1 ; **1732** ; 1750 + 6 ; 1767 W.–E. + *6*, felt at Gallipoli ; 1770 ; 1777 ; 1780 + 1 ; **1783** + *25*, one of the most disastrous ever felt in Europe ; Hamilton gives as centre Oppido, and as limits two circles, one of 22 Italian miles radius, the other of 72 Italian miles ; the smaller circle includes all the places where the earthquake was destructive + 2 ; 1784 + 7 ; 1785 + 3 ; 1788 + 2 ; 1789 ; 1790 + 3 ; 1791 + 1 ; 1798 ; 1799 + 1 ; 1805 ; 1818 S.E.–N.W. + 1 ; 1825 + 5 ; 1832 S.E.–N.W. + 3 ; 1839 + 1 ; 1840 ; 1841 + 2 ; 1843 + 1 ; 1846 ; 1852 + 4 ; 1853 ; 1858 ; 1869, centre on the Tyrhenian slope, between the rivers Mesenia and Lamato + 1 ; *1870* + 9 ; 1871 ; 1874 ; 1881 S.–N. + 1 + 1, between Calabria and Sicily, centre at Gioja-Fauro, extended parallel to mountains from Aspramonte.	215
CALABRITTO, . . .	Calabria, ...	1853.	1
CALAIS, ...	. . . . .	1580 ; 1671.	2
CALAMARA, . . .	Messenia Prov., Greece, .	1846.	1
CALAMATTA = KALAMATTA,	Morea, ...	1842 + 2 ; *1846 + 10*, also town of Nisi, Bourg of Muromani ; villages of Asptroochomatos, Calamios, Aslan Aga, Baliaga, Garizogli, Basta, Gliata, Kourkoutzi, Phoutzala, Pharmitzi, Delimeri, Veis Aga, Kalami, Katzikovi. Hospitakia, Kartipoli, Peperiksa, Anaziri, Hassan Pacha, Calamarra, Aloupochosi, Maoromati ; 1860 + 1 ; 1861 + 1 ; 1862 ; 1864 ; 1866 + 1 ; 1867 + 5.	28
CALAMIOS, . . .	Messinia Prov., Greece, .	1846.	1
CALCHIS, PROVINCE, .	Greece, ...	1853.	1
CALCHIS, CITY, . .	,, ...	1853 + 40 ; 1854 ; 1866 + 10 ; 1867 + 5.	59
CALCI, . . . near	Pisa, ...	1846 + 1.	2
CALDAS DOS TYPES, .	Portugal, ...	1856.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CALDAS, ...	Portugal, ...	1857.	1
CALDAROLA, . . .	Macerata Province, Italy, .	(1871 + 19) S.–N.	20
CALENZANA, . . .	Corsica, ...	1858.	1
CALL, ...	Schleiden C., Rhen. Prussia,	1869 + 1.	2
CALLA ISLAND, . .	Scotland, ...	1880.	1
CALLAHORRA, . .	. . . . .	1817.	1
CALLENDER, . . .	Scotland, ...	1801 ; 1880.	2
CALLINGTON, . . .	Cornwall, ...	1860.	1
CALTAGIRONE, . .	Sicily, ...	1852 ; 1866 ; 1870.	3
CALOW, ...	Würtemberg, . . .	1855.	1
CALTANISETTA, . .	Sicily, ...	(1823 + 4) N.E.–S.W. ; 1844.	6
CALVADOS Department, .	. . . . .	1847.	1
CALVELLO, . . .	Basilicata, ...	1857 + 5 ; 1858 + 3.	10
CALW, ...	Würtemberg, . . .	1871 + 3.	4
CAMBLANES, . . .	Gironde, ...	1852.	1
CAMBERG, . . .	Nassau, ...	1869.	1
CAMBOURNE, . . .	. . . . .	1842.	1
CAMBRESIS, . . .	. . . . .	922.	1
CAMBRAI, . . .	Nord, ...	1857.	1
CAMBO, ...	Basses Pyrenees, . . .	1858.	1
CAMELFORD, . . .	. . . . .	1757 ; 1837 + 3.	5
CAMON, ...	Somme, ...	1784.	1
CAMERINO, . . .	Lower Po Valley, . .	1859 ; 1870 ; 1871 + 9 ; 1875 + 1 ; 1882 + 3 ;	18
CAMPAGNA, LA, . .	. . . . .	325 ; 344 ; 1004 ; 1794 ; 1826 ; *1853*, centre at Caposele and Calabrito, + 69.	75
CAMPAGNA, . . .	Calabria, ...	1853.	1
CAMPI, . . . near	Norcia, ...	1859 + 3.	4
CAMPLETOWN, . .	. . . . .	1880.	1
CAMPO, ...	Portugal, ...	1848.	1
CAMPOBASSO, . . .	Molise, Italy, . . .	1805 ; 1853 ; 1874.	3
CAMPODOLEINO, . .	Val Liro, ...	1880, extended over surface of 18 km. R.	1
CAMPOLATTRO, . .	Benevento Province, Italy, .	1853.	1
CAMPOLI, . . .	Terra di Lavoro, . . .	1842.	1
CAMPOMARZO, . .	Pontevedra, Galicia, Spain, .	1854.	1
CAMPORA, . . .	Principato, Italy, . .	1832.	1
CAMPREVEYRIS, . .	Switzerland, . . .	1870.	1
CAMPS, ...	Nassau, ...	1841.	1
CAMPSIE, . . .	Scotland, ...	1845.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CANAR, ...	4 km. from Orgivia, Almeria, Prov., Spain, . . .	1863.	1
CANARA, ...	Perugia, ...	1832, extended along a line parallel to the Appenines.	1
CANALE, ...	Carniola, ...	1876.	1
CANALI, . . . near	Cattero, Dalmatia, . .	1853 E.–W.	1
CANCALE, . . .	Ile et Vilaine, . . .	1804.	1
CANDIA or CRETE ISLAND,	. . . . .	365; 795; 1246; 1303; 1490; 1501; 1508; 1569; 1612; 1650; 1662; 1665 + 1; 1673; 1681 + 8; 1780; *1805* + 3, also felt in Sicily; 1810; 1818; 1846 + 2; *1856 + 1*, traversed the Mediterranean; 1857; 1858 + 2; 1863, felt at Beyruth, Gallipoli, Smyrna, Chios and Cos; 1866 + 4; 1867 + 1; 1870 + 1; 1871; 1876.	51
CANDIA, 35 miles west of,	. . . . .	1843.	1
CANEA, ...	Crete, ...	(1779 + 2) E.–W.; 1794 + 1; 1846; 1861 + 5; 1862 + 1 + 3 + 3 N.–S.; (1867 + 2) N.–S.; 1870; 1876; 1877; (1879 + 2) N.–S. + 1; (1881 + 2) W.–E.; (1882 + 2) W.–E.	36
CANDES, ...	Indre et Loire, . . .	1840.	1
CANIGOU, . . .	Pyrénées, Orientales, . .	1755; 1843.	2
CANNES, ...	Alpes Maretimes, . .	1854 + 2; 1876.	4
CANNOBIO, . . .	Pallanza, Italy, . . .	1880 + 1.	2
CANOSA, ...	Basilicata, ...	1851 + 3; 1856 + 2; 1857 E.–W.; 1858 + 1.	10
CANSTADT, . . .	Suabia, Würtemberg, . .	1750; 1755; 1855.	3
CANTALEGNO DISTRICT, .	N. Kg., ...	1854.	1
CANTAL, ...	Auvergne, ...	1833 + 6.	7
CANTORIA, . . .	Andalucia, ...	1863 + 16.	17
CAPELLEN, . . .	Coblentz C., Rhen. Prussia,	(1869 + 1) N.W–S.E.	2
CAPILEIRA, . . .	Sierra Nevada, Spain, . .	1863 + 2.	3
CAPITANATA, LA, . .	. . . . .	1626 + 7; 1821 E.–W. + 7.	16
CAPIZZI, ...	Sicily, ...	1822.	1
CAPO DI ORLANDO, .	Sicily, ...	1823 + 4.	5
CAPO DI CALAVA, . .	. . . . .	1823.	1
CAPO SPULICO, . .	Calabria, ...	1870.	1
CAPOSELE, . . .	,, ...	1853.	1
CAPRAROLA, . . .	Spoleto, ...	1881 + 1.	2
CAPRI ISLAND, . .	. . . . .	1791.	1
CAPUA, ...	. . . . .	982; 990; 1231, extended to Rome; 1694; 1805.	5
CARAMIENICO, . .	Abruzzi, ...	1841.	1
CARCASSONE, . . .	Aude, ...	1776; 1824 + 1.	3
CARDEN, ...	Rhine Valley, . . .	1869.	1
CARDIFF, . . .	. . . . .	1839; 1865; 1868.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CARDONA,	Cataluña, Spain,	1845.	1
CAREGA,	Novi,	1882.	1
CARGEN,	Dumfries,	1865.	1
CARIA,	Asiatic Greece,	B.C. 224; A.D. 150.	2
CARIATI,	Calabria Cit.,	1831 + 13.	14
CARICO,	Sicily,	1865; 1867.	2
CARINTHIA,		1348; (1811 + 1) S.E–N.W.; 1869; 1878; 1880, seemed to extend along the Karawauken chain of mountains; 1881.	7
CARINTHIA, Upper,		1866 N.–S.; 1876.	2
CARINTHIA, Middle and Lower,		1879.	1
CARINTHIAN ALPS,		1881, extended by the Karst Valley to Trieste—limits: Fiume, Trieste, Görtz, Laybach, Klagenfurt.	1
CARINTI,	Calabria Cit.,	1831 + 1.	2
CARLISLE,		1871.	1
CARLETTO,	N. Kg.,	1857.	1
CARLOFORTE,	Sardinia Island,	1856 + 1.	2
CARLOWITZ,	Hungary,	1788.	1
CARLSRUHE,	Baden, S.W. Germany,	1734 + 74; 1822; 1837; 1869 + 1; 1874; 1880 + 1.	82
CARLSBAD,	Saxony,	1850; 1862.	2
CARLSFELD,	Saxon Voigtland,	1862 + 2.	3
CARLSTADT,	Transylvania,	1691; 1843 N.–S. + 3; 1853.	6
CARMAGNOLE,	Piedmont,	1703 + 1.	2
CARMONA,	Andalucia,	1504.	1
CARNARVON,		1780.	1
CARNARVONSHIRE,		1874.	1
CARNIOLA,		1081; 1118; 1855; 1863; 1868 S.W. + 3; 1879; 1881; 1882, the zone of greatest action lay between Laybach and Loitsch.	11
CARNAT,	Lesachthal, Carinthia,	1881 N.W.–S.E.	1
CARNITIC ALPS,		(1881 + 2) E.–W.	3
CAROCETO, near	Urbino,	1853; 1870.	2
CAROLEI,	Calabria Cit.,	1854.	1
CARPATHOS ISLAND,	Grecian Archipelego,	1856.	1
CARPENTRAS,	Vaucluse,	1737; 1863.	2
CARPETHIAN Mountains,		1840; 1866.	2
CARRARA,		1740; 1784.	2
CARTAL or CARTOL,	North Asia Minor,	1871.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CARTHAGENA, . .	. . . . .	1747; 1761; 1777 + 3; 1786; 1790; 1804; 1823 + 3; 1829 + 1; 1833 + 3; 1834 + 5; 1844; 1851; 1855 + 9; 1856 + 4; 1860; 1863 S.–N. + 1 + 1 N.–S.; 1864 + 2 + 1 E.–W.; 1874 + 1.	52
CARTMILL, . . .	. . . . .	1786.	1
CASAGLIA, . . .	Maurienne, Savoy, . .	1848 + 1.	2
CASALE, ...	Tuscany, ...	1846; 1871.	2
CASALECCHIO DEI CONTI,	Romagna, ...	1881 + 4 + 2 S.E.–N.W.	7
CASALETTO, . . .	Calabria Cit., . . .	1858 + 5.	6
CASALI, . . . near	Norcia, ...	1859 + 2.	3
CASAL-MAGGIORE, .	Cremona, Italy, . . .	1756.	1
CASAL-NUOVO, . .	Naples, ...	1851.	1
CASCAES, . . .	Portugal, ...	1756 + 3; 1757.	5
CASCIA, ...	Ombria, ...	1703; 1730 + 3; 1859; 1871 + 31; 1882 + 3.	42
CASCIANA, . . .	Tuscany, ...	1846; 1847; 1848.	3
CASCINA, . . .	Pisa, ...	1846; 1848.	2
CASA MICCIOLA, . .	Ischia Island, . . .	1828; *1881*, town partly destroyed, + 12.	14
CASENTINO, . . .	Tuscany, ...	1856.	1
CASERTA, . . .	Terra di Lavoro, . . .	1780; 1794; 1805; 1853; 1873; 1875.	6
CASIGNOLA, . . .	. . . . .	1851 E.–W.	1
CASIGNO, ...	Bologna, ...	1874.	1
CASOLA, ...	Terra di Lavora, . . .	1725 + 3.	4
CASOLI, ...	Abruzzo Cit., . . .	1863 N.–S.; 1864 + 6; 1871 + 1.	10
CASONE, . . . near	Verona, ...	1882 + 1.	2
CASOS ISLAND, . .	Grecian Archipelego, . .	1856; 1863.	2
CASSABA, . . .	Asia Minor, . . .	1867; 1880.	2
CASSANO, . . .	Terra di Barri, . . .	1845.	1
CASSEL, ...	. . . . .	1756; 1767; 1872.	3
CASSELER LEY MOUNTS.,	Rhine Valley, . . .	1869.	1
CASSINE, ...	Piedmont, ...	1866; 1881 E.–W.	2
CASSOTIS, . . .	Corinth Gulf, . . .	1870.	1
CASTANET, . . .	Haute Garonne, . . .	1854.	1
CASTASIGNA, . . .	Grisons, ...	1882 + 1.	2
CASTEL BUONO, . .	Sicily, ...	1823 + 1; 1871 S.W.–N.E.	3
CASTEL DI FERRO, .	20 km. from Motril, Almeria [Prov.	1863 + 2.	3
CASTEL D'AYANO, .	Bologna, ...	1864 S.E.–N.W. + 4 + 7 S.–W.	12
CASTEL DELPHINO, .	Salluzi, ...	1881.	1
CASTEL FIORENTINO, .	Firenze, ...	1768 + 1; 1846 S.W.–N.E. + 2; 1869 + 4.	10
CASTEL FRENTANO, .	Abruzzo Cit., . . .	1881 + 2; 1882 + 6.	10

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CASTEL GONDOLFO, .	. . . . .	1785 + 1 ; 1829 + 14 ; 1868 ; 1869.	19
CASTEL JALOUZ, . .	Lot et Garonne, . . .	1854.	1
CASTELLAUM, . .	Semmerin C., Rhen. Prussia,	1869 + 4.	5
CASTELLANE, . .	Var, ...	1842 + 1.	2
CASTELLANE, . . .	Basses Alpes, . . .	1855, R. = 15 km., + 7.	8
CASTELLARO, . . .	Pignerol, ...	1831 + 1.	2
CASTELLO, . . .	Lago di Guarda, . . .	1866 + 35.	36
CASTELLAMARE, . .	Principato, ...	1694 ; 1856 ; 1867.	3
CASTELL LASTUA, .	Adriatic Coast, . . .	1877 ; 1880 ; 1881.	3
CASTELLORIOSO, . .	Konieh, Anatolia, . .	1856.	1
CASTELLO DI FAENZA,	. . . . .	1880 + 7.	8
CASTELLETO TICINO, .	Piedmont, ...	1881.	1
CASTELLATO DEL BREZONE,	Verona, ...	1881 + 1.	2
CASTELLOROSSO ISLAND,	Grecian Archipelego, . .	1856.	1
CASTEL NUOVO, . .	Roman States, . . .	1672 ; 1831 + 2.	4
CASTEL NUOVO DI CATTARO,	. . . . .	1863 + 1.	2
CASTEL NUOVO DI MISERICORDIA, Tuscany,	. . .	1846 + 1 + 1 + 4.	7
CASTEL PORZIANO, .	Roman States, . . .	1855.	1
CASTEL ST. PIETRO, .	Bologna, ...	(1881 + 1) S.E.–N.W.	2
CASTEL SARACENO, .	Basilicata, ...	1857 + 5.	6
CASTEL SARREZIN, .	Garonne, ...	1743 + 1.	2
CASTEL SAVONNO, .	N. Kg., ...	1857.	1
CASTIGLIONE, . .	Roman States, . . .	1695 ; 1771 ; 1818.	3
CASTIGLIONE, . .	Calabria Cit., . . .	1835 + 10 ; 1882.	12
CASTIGLIONE DI RAVENNA,	. . . . .	1881.	1
CASTIGLIONE DELLE STIVIERE, Mantua, .	. . . .	1771 + 1 ; 1851.	3
CASTILLE, . . .	. . . . . , .	1817 ; 1861 + 1.	3
CASTILLON, . . .	Dordogne, ...	1852 N.–S., extended from Bordeaux, through the Gironde to Pau, and to Royan, Saintes, Rochefort, and La Rochelle, and to Maremines in the north ; 1854 N.–S.	2
CASTIONE, . . .	Bergamo, ...	1882.	1
CASTLEBRIDGE, . .	Co. Wexford, Ireland, . .	1832.	1
CASTRASEGNA, . .	Switzerland, . . .	1871 + 1 N.–S.	2
CASTRIGNANO, . .	Terra di Otranto, . .	1832.	1
CASTROCALE, . . .	Romagna, ...	1717 ; 1781.	2
CASTROCARO, . . .	Italy, ...	1870 + 1.	2
CASTROREALE, . .	Messena, Sicily. . . .	1846 + 1.	2
CASTRO VILLARI, . .	Calabria Cit., . . .	1841 ; 1843 + 2 ; 1845 ; 1855 + 3 ; 1856 + 1 ; 1858 + 1 ; 1869 ; 1871 ; 1881 S.–N.	16

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CASTUA, ...	Istria, ...	1870 + 1.	2
CASTANIA, ...	Sicily, ...	1173; 1635; 1693 + 3; 1694; 1698; **1699** + 2; 1716 + 1; 1717; 1718; 1817; (1818 + 1) S.E.–N.W. + 3; 1819; 1822 + 1; 1823; *1830* + 1; 1832; 1842 + 1; 1844; 1846 + 4; 1847; 1848; 1849 + 1; 1850 + 1; 1864; 1865; 1866; 1867 + 5; 1868 + 1; 1870; (1871 + 1) W.–E. + 2 N.–S.; 1877; 1878 + 42; 1880; 1882 S.–N.	104
CATALUÑIA Province, .	Spain, ...	1420; **1431**; 1817; 1852 + 2; 1868.	7
,, ,, .	Eastern part of, . . .	1853.	1
CATANZARO, . . .	Calabria, Italy, . . .	1821 + 3; 1822 + 1; 1824 + 3; 1825 + 2; 1826 + 3; 1832 + 4; 1841; 1842; 1851 + 4; 1854; 1855 + 1; 1856 + 2; 1860; 1865 + 1 W.–E. + 2; 1866 S.–N. + 1; 1867; 1869 S.–N. + 1 E.–W. + 3; 1870 + 1 + 1 E.–W. + 6 + 1 N.–S.; 1871 + 1; 1877 + 3; 1881.	65
CAUCERES, ...	Estremadura, . . .	1858 + 1.	2
CAUDEBEC, . . .	Normandy, ...	1878.	1
CAUMACRE, . . near	Tours, ...	*1841* N.–S.	1
CAUMONT, . . .	Calvados, ...	1802.	1
CAUTERETS, . . .	Hautes Pyrénées, . .	1850; 1852; 1854 + 12; 1855; 1868 N.–S. and in the Thermal chain of the Pyrenees, + 1.	18
CAVA, ...	Calabria, ...	1720; 1844.	2
CAVALLA, . . .	Macedonia, ...	1867 + 4.	5
CAVALLER MAGGIORE,	Piedmont, ...	1858; (1878 + 1) E.–W.	3
CAVALLINA, . . .	Mugello, ...	1854 N.E–S.W.	1
CARALLON, . . .	Vaucluse, ...	*1731*.	1
CAVENGO, . . .	Bulluno Territory, . .	1873.	1
CAVOUR, ...	Piedmont, ...	1808 + 6; 1809; 1858 + 2.	11
CAVO MOUNTAINS, .	Bologna District, . .	1881.	1
CAYLUS, ...	Lot, ...	1802.	1
CÉAUCÉ, ...	Orne, ...	1848.	1
CECCANO, . . .	Frosinone, Italy, . .	1133; 1160; 1161; 1170; 1200; 1880; 1881.	7
CELICO, ...	Calabria, ...	1870.	1
CELIGNY, . . .	Vaud C., ...	1881.	1
CELLA, ...	Cremona, ...	1784, R. = 3 leagues.	1
CELLENO, . . .	Viterbo, ...	1695; 1881 E.–W.	2
CELORICO DI BASTO, .	Portugal, ...	1856.	1
CELVEINA, . . near	Silvaplana, Upper Engadine,	1852 E.–W. + 3.	4
CENEDA, ...	Treviso Province, . .	1859.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CEPHALONIA ISLAND, .	. . . . .	*1658*; **1714**; 1736; 1743; 1752; 1766 + 50, continued for 50 days; 1767 + 2; 1783; *1784* + 3; 1834 + 1; 1837; 1862 + 32 + 1 N.W.–S.E.; 1863 + 2; 1864; 1865 + 4; 1866 + 6; 1867 + 1, + 90 × 20, + 20 × 10, + 5 × 30, + 50 × 5; 1868 + 4; 1876 + 3, extended over all the Ionian Islands and the coast of Greece.	2618
CERAMI, ...	Sicily, ...	1853.	1
CERASO, ...	Salerno Province, . .	1878 E.–W. + 1.	2
CERAZO, ...	North Italy, . . .	(1878 + 1) E.–W.	2
CERIGO ISLAND, . .	Between it and Morea, .	1866.	1
CERIGO ISLAND, . .	. . . . .	**1750**, the town ruined, more than 2,000 people killed; 1867 + 3.	5
CERISINO, . . .	Calabria Cit., . . .	1854.	1
CERTALDO, . . .	Firenze, ...	1869.	1
CERVERA, . . .	Cataluña, Spain, . .	1852 N.–S.	1
CESENA, ...	Forlì, ...	1331 + 17; 1334; 1653; 1781; 1801 + 2; 1828; 1855; 1870; 1881 S.E.–N.W.; 1882.	29
CESENA, ...	Calabria Cit., . . .	1653 + 3; 1854 + 1; 1871.	7
CESENATA, . . .	Ravenna Dis., . . .	1875.	1
CESARO, ...	Messina, Sicily, . . .	1822.	1
CESME ISLAND, . .	Anatolia Coast, . . .	*1852* + 3 + 1 S.E.–N.W.	5
CETONA, ...	Arezzo, ...	1854; 1861 + 4.	6
CETIGNE, . . .	Montenegro, . . .	1857 + 1; 1880 + 2.	5
CETTE, ...	Hérault, ...	1841.	1
CEUTA, ...	Marocco, ...	1755 + 16.	17
CEVOLI, ...	Pisa, ...	1851.	1
CHAGFORD, . . .	. . . . .	1858.	1
CHALABRE, . . .	Aude, ...	1837.	1
CHALINDREY, . .	Haute Marne, . . .	1862.	1
CHÂLONS SUR SAÔNE,	. . . . .	1784; 1841; 1846; 1855; 1871.	5
CHAM, ...	Bavaria, ...	1872.	1
CHAMAKHI, . . .	Chirvan Prov., Caucasus, .	*1859*, town destroyed.	1
CHAMPAGNE, . . .	. . . . .	1719.	1
CHAMBERY, . . .	Savoie, ...	1755 N.E.–S.W.; 1784; 1808 S.–N.; 1822 + 1; 1824; 1840 E.–W.; 1841; 1844 N.–S.; 1851; 1854; 1855 E.–W.; 1856, R. = 2 leagues, + 1 E.–W. + 1; 1858; 1866; (1876 + 1) N.W–S.E.; 1881 + 1 N.E.–S.W. + 1.	22
CHAMOUNIX VALLEY, .	. . . . .	1803; 1817; 1851; 1881 N.E.–S.W. + 1.	5
CHAMPIGNOLES, . .	Jura, ...	1857.	1
CHAMPIGNY, . . .	Loire et Cher, . . .	1864.	1
CHANDOLLE, . . .	. . . . .	1857.	1
CHANGON MINE, . .	Navarre, ...	1853.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CHANGERI (Chanli-Killissa,	Kurdestan, . . .	1881.	1
CHANNEL ISLANDS, .	. . . . .	1843.	1
CHANNEL, ENGLISH, .	. . . . .	1671.	1
CHANTELLE, . . .	Allier, ...	1854 ; 1863 ; 1879.	3
CHAPARCILLAN, . .	Savoie, ...	1856.	1
CHAPELLES, LES, . .	Maurienne, ...	1847.	1
CHARENTE, Department,	. . . . .	1783.	1
CHARENTE, Inf. Dept., .	. . . . .	1873.	1
CHARELLES, . . .	Entre Autun et Besançon, .	1784.	1
CHARLEVILLE, . .	Ardennes, ...	1755 ; 1878.	2
CHARLEROI, . . .	Belgium, ...	1881 + 7.	8
CHARLOTTENBERG, .	Brandenburg, Prussia, .	1846.	1
CHAROLLES, . . .	Saône et Loire, . . .	1855.	1
CHARMAKHI, . . .	Chirvan Province, Tiflis, .	*1859.*	1
CHARNWOOD FOREST,	. . . . .	1838.	1
CHARTRES, . . .	. . . . .	1579 ; 1841.	2
CHATEAU GIRON, . .	Ille et Vilaine, , . .	1843 + 1.	2
CHATEAU NEUF, . .	Languedoc, ...	1840 ; 1873 + 2.	4
CHATEAU NEUF, . .	Maurienne, ...	1847.	1
CHATEAU D'ŒZ, . .	Vaud C., ...	1835 ; 1878, extended to Lausanne, + 1 ; 1881 + 3.	7
CHATEAUROUZ, . .	Indre, ...	1800 ; 1801 + 3 ; 1847 ; 1857.	7
CHÂTEL, ...	Moselle, 11 km. N. of Epinal,	1851.	1
CHATILLENS, . . .	Vaud C., ...	1881.	1
CHATILLON, . . .	Aosta Valley, . . .	1783 ; 1840.	2
CHATILLON sur Saône, .	Vosges, ...	1862 + 1.	2
CHATILLON sur Indre, .	. . . . .	1841 + 1.	2
CHAUM, ...	Haute Garonne, . . .	(1855 + 5) N.E.–S.W.	6
CHAUMONT, . . .	Haute Marne, . . .	((1862 + 1) N.–S.	2
CHAUNY, Canton, . .	Aisne, ...	1873 + 1.	2
CHAUX DE FONDS, .	Neuchatel, Switzerland, .	1756 + 1 ; (1854 + 1) N.–S. ; 1855 S.E.–N.W. ; 1856 N.E.–S.W. + 1 ; (1858 + 3) E.–W. ; 1880 ; 1881 + 1 ; 1882.	15
CHAVAGNES, . . .	Vendée, ...	1867.	1
CHAVANNES, . . .	Ain, ...	1882.	1
CHEBLI, ...	Algeria, ...	1869 + 1 S.W.–N.E.	2
CHEDDER, . . .	. . . . .	1852 + 2.	3
CHEDSEY, . . .	. . . , . . .	1680.	1
CHEKOUD-CASSABA, .	Anatolia, ...	1862 + 5.	6
CHELIF, Valley of, .	Algeria, ...	1868.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CHELSEA, . . .	. . . . .	1750.	1
CHEMNITZ, . . .	Saxony, ...	1857 ; 1869 ; 1872.	3
CHENEVE, . . .	Burgundy, ...	1882 S.–N.	1
CHENKOWSK, . . .	Archangel, G. Russia, . .	1829 + 2.	3
CHER, DEPARTMENT, . .	. . . . .	1837 + 1.	2
CHERCHEL, . . .	Algeria, ...	1845 + 28 ; 1846 + 3 ; 1847, shocks every day from November 1846 to June 1847, or about 500 altogether) ; 1855 S.–N. ; 1857 ; 1858 + 2 ; 1862 E.–W. ; 1865 ; 1867 ; 1874 N.–S. + 1 ; 1876 + 1 ; 1877.	537
CHERCHIARA, . .	Abruzzo Ultra, . . .	1843 + 3.	4
CHERBOUG, . . .	. . . . .	1750 ; 1822 + 1 ; 1843 ; 1853 ; 1860 S.–N.	6
CHERSO, ...	Illyria, ...	1870.	1
CHERSON, . . .	. . . . .	1790.	1
CHERSONESSUS, . .	. . . . .	B.C. 282 ; A.D. 447.	2
CHERSTON BISHOPS, .	. . . . .	1858.	1
CHESME ISLAND, . .	Anatolia, ...	1852 + 3 + 1 S.E.–N.W. ; 1881 + 1 + *2*.	9
CHESSY, ...	Rhône, ...	1824 ; 1841.	2
CHESTER, . . .	. . . . .	1750 ; 1777 ; 1800.	3
CHEVREUSE, . . .	Seine et Oise, . . .	1841 N.E.–S.W.	1
CHEVRON, . . .	Savoie, ...	1852.	1
CHEYLAND, . . .	Drôme, ...	1856 + 1.	2
CHANCIANO, . . .	Arezzo, Italy, . . .	1849 + 6 + 1 N.E.–S.W. + 2 N.–S.	10
CHIANO-DI ARREZO, .	. . . . .	1847.	1
CHIANZINO, . . .	Padua District, . . .	1861.	1
CHIARAMONTE, . .	Sicily, ...	1819.	1
CHIARAVALLE, . .	Calabria, ...	1869.	1
CHIATIMONE, . .	. . . . .	1820.	1
CHIAVENNA, . . .	Sondrio, Italy, . . .	1755 ; 1851.	2
CHIAVARI, . . .	Piedmont, ...	1852 N.–S.	1
CHICHESTER, . .	. . . . .	1638 ; 1734 ; 1824 ; 1833 ; 1834 + 4 ; 1835.	10
CHIETI, ...	Abruzzi, ...	1719 ; 1765 ; 1805 ; 1840 + 3 ; 1842 ; 1845 ; 1846 + 1 ; 1850 + 3 ; 1871 ; 1881 ; 1882 + 3.	18
CHIFFA, ...	Algeria, ...	1869.	1
CHILMLY, . . .	Caucasus, ...	1869.	1
CHINÈVE, . . .	Côte d'Or, ...	1882 S.–N.	1
CHINON, ...	Indre et Loire, . . .	577.	1
CHIMARRA, . . .	Grecian Archipelago, . .	1858.	1
CHIOGGIA, . . .	Venice, ...	1869 + 2 ; 1870.	4
CHIORGAS, . . .	Rhodes Island, . . .	1851.	1
CHIRVAN (*see* SHERVAN).			

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CHIUSI, ...	Arezzo, ...	1849; 1861 N.–S. + 7.	9
CHIOS ISLAND, . .	. . . . .	B.C. 22; A.D. 1508; 1688; 1820; 1845; 1850; 1855 E.–W. + 1; 1856; 1859; 1860 + 1; 1861 + 3; 1862; 1863; 1865 + 50 + 1; (1866 + 5 + 3) E.–W. + 2; 1867 + 14; 1876 + 5; 1880; 1881 + 13 + *3*, extended to Syria and Smyrna —very destructive,—the centre at Nevida, on the east coast of the Island. The town ruined—out of 70,000 inhabitants, 4,181 killed, 10,000 wounded, 14,000 houses destroyed, + 251 shocks, each of these shocks could destroy the strongest wall. The island sank 1 m. and the sea bottom between the Island and the land raised from 45 fathoms depth to 15 fathoms depth; 1882, extended to Smyrna, + 4.	375
CHLUMITZ, . . .	Enciente de Wettengau, [Bohemia,	1860 + 3.	4
CHORAL, ...	Pultava, South Russia, .	1829 + 1.	2
CHOTIN, ...	Bessarabia, S.W. Russia, .	1838 + 1.	2
CHOUCHA (Schousa), .	Lat. 39° 46′, Long. 44° 23′, } Caucasus,	1861 + 2; 1853 + 1; 1862 + 1; 1869 + 2; 1879 + 1.	12
CHRISTIANSHAVEN, .	Denmark, ...	1829.	1
CHRISTIANSAND, . .	Norway, ...	1745, extended to the sea and Hellesand Island, on the same day a shock at Copenhagen; 1786; 1793; 1866.	4
CHRISTIANA, . . .	Norway, ...	1657; 1780; 1803 E.–W.; 1823 + 2; 1834 E.–W.; 1865; 1875.	9
CHRISTIAN ISLAND, near	Bornholm, ...	1783 + 2.	3
CHTCHEDRINE, . .	Lat. 43° 28′, Long. 43° 48′, } Caucasus,	1853 + 1.	2
CHULFORD, . . .	. . . . .	1865.	1
CHURWALDEN, . .	Grisons, ...	1878; 1882.	2
CHRYSE ISLAND, . near	Lemnos, ...	B.C. 323.	1
CHRYSO, ...	Corinth Gulf, . . .	1870.	1
CICLANE, . . .	Spanish Coast, . . .	1773.	1
CIENFS, ...	Grisons, ...	1882 + 1.	2
CIENTRUENIGO, . .	Cataluña, Spain, . .	1817.	1
CILICIA, ...	. . . . .	**1268**, 60,000 lives lost.	1
CILLARA, . . .	Calabria, ...	1870 + 1.	2
CILLY, ...	Styria, ...	1855 + 1 + 2 S.E.–N.W.; 1856; 1857 + 2; 1858 S.W.–N.E.; 1861 + 1; 1862; 1863; 1870, felt also at Racovac and at Agram, + 2; (1877 + 2) S.W.–N.E.; 1880 N.E.–S.W. + 5; 1881 + 1 + 1; 1882.	29
CIMINI LACUS, . .	Central Italy, . . .	B.C. 1450, a city swallowed up and the lake formed.	1
CINOSA, ...	Otranto Province, . .	1836.	1
CINSISHEIM, . . .	. . . . .	1855.	1
CINTRA, ...	Portugal, ...	1756 + 1; 1788 + 1; 1857; 1858 + 1.	7
CINTRA MOUNTAINS, . .	,, ...	1756.	1
CIRIGNOLA, . . .	Capitanata, ...	1881.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CIRO,	Calabria,	1832.	1
CITTA DE LA PIEVE,		1861 + 51.	52
CITTA DUCALE,	Abruzzi,	1853; 1854; 1856; 1859 + 2; 1881 + 5.	12
CIVIDALE,	Venetia,	1872 + 2.	3
CIVITA VECCHIA,		(1869 + 2) N.N.W.–S.S.E.	3
CIVITA VECCHIA,	Malta,	1856 + 1.	2
CIVITELLA,	Ancona Marches,	1752; 1753.	2
CLAGENFURT,	Carinthia,	1767 + 1; 1785 + 2; 1804 + 2; 1830; 1840 S.W.–N.E. + 1; 1845 N.W.–S.E., same hour at Laybach, extended to Prevali, Forlach, Tigring, St. Veit, Offiach, Lesireg, and Tarvis; 1846 + 1; 1847; 1850 S.–N.; 1854 N.–S.; 1855 + 1; 1856 + 3 + 1 N. + 1; 1857 + 4 + 1 W.–E.; 1858 + 1; (1860 + 1) N.W.–S.E. + 1; 1862 + 7; 1863; 1864 N.–S.; 1868 + 1; 1873; 1879 + 1 + 1 N.E.–S.W.; 1880 S.E.–N.W. + 3 N.–S. + 1; 1881 + 3 + 1 E.–W. + 3 W.–E.; 1882 W.–E.	66
CLAIRAC,	Lot et Garonne,	1814.	1
CLAROFKA, near	Cherson,	1838 + 1.	2
CLATHECK,	2 miles east of Comrie,	1843.	1
CLAUSSEMBERG,	Danube Basin,	1785.	1
CLAUSSENBERG,	Transylvania,	1786.	1
CLAUSSAYES,	Drôme,	(1772 + 4) E.–W. + 6; (1873 + 18) E.–W. + 1 + 12 + 3 S.–N.	46
CLEFMONT,	Haute Marne,	1784.	1
CLERMONT,	Auvergne,	1752; 1755 + 1; 1785; 1804; 1822; 1855 E.–W.; 1857 + 1; 1863 + 1; 1866; 1877 + 1.	14
CLERMONT,	Oise,	1756.	1
CLEURIE,	Vosges,	1859.	1
CLEVES,	Rhenish Prussia,	1867; 1878.	2
CLIFFE,		1844.	1
CLIFFORD,	Herefordshire,	1863.	1
CLIFTON,		1852.	1
CLITHERO,		1855; 1863.	2
CLONTARF,	Dublin,	1852.	2
CLUNEUR,	Sweden,	1759 + 3.	4
CLUSAVERA,	Northern Italy,	1881.	1
CLÜSERATH,	On the Moselle,	1869.	1
CLUSONE VALLEY,	Piedmont,	1808 + 1.	2
CLWYDVALE,	Wales,	1780; 1805.	2
CNIDOS,		A. D. 477.	1
COBERN,	Moselle Valley,	1869 + 2.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
COBLENTZ, . . .	. . . . .	1780 + 3 ; 1828 ; 1830 ; 1837 ; 1838 + 1 ; 1841 N.E.–S.W., extended along the Moselle, the Rhine, and the Lahn ; 1842 + 1 ; (1861 + 2) N.–S. ; 1869 + 6 + 2 W.–E. ; 1870 + 1 N.–S.	26
COBOURG, . . .	S.W. Germany, . . .	1847.	1
COCŒNA, ...	E. Bothnia, Sweden, . .	1764.	1
COFFRANE, . . .	Neuchatel C., Switzerland, .	1855 + 1 + 1 N.W.–S.E.	3
COGNAC, ...	. . . . .	1822.	1
COÌMBRE, . . .	Portugal, ...	1857 ; 1880.	2
COIRE (CHUR), . . .	Grisons, ...	1802 ; 1805 + 3 ; 1813 ; 1826 ; 1828 ; 1839 S.W.–N.E. ; 1850 ; 1851 ; 1853 ; 1856 ; 1857 ; 1861 ; 1863 + 1 ; 1868 ; 1871 ; 1878 ; 1880 S.–N. + 2 ; 1882.	24
COLARES, . . near	Lisbon, ...	1755 + 10 ; 1756 + 3.	15
COL DI TENDA, . .	Nice, ...	1849, immense crevasses formed, + 1 ; 1854.	3
COLI, ...	Parma, ...	1882 + 3.	4
COLEBROOKDALE, .	. . . . .	1783.	1
COLICO, ...	Lake Como, . . .	1850.	1
COLLALTO, . . .	Treviso Province, . .	1858 + 22, up to 12th Feb., + 2 ; 1859 + 34 ; 1860.	61
COLLE D'ELSA, . .	Tuscany, ...	1804 ; 1856 + 9.	11
COLLECHIO, . . .	Parma, ...	1835.	1
COLLE DI VALDOBBIO,	Piedmont, ...	1881.	1
COLLIANO, . . .	Calabria Ultra, . . .	1853.	1
COLLIEURES, . . .	E. Pyrénées, . . .	1797 + 1 ; 1824.	3
COLLIO, ...	Brescia, ...	1871.	1
COLLO, ...	Algeria, ...	1869 W.–E.	1
COLLYWESTON, . .	. . . . .	1844.	1
COLMAR, ...	. . . . .	1674 ; 1801 ; 1829 N.–S. + 3 ; 1843 ; 1855 W.–E..	8
COLOGNÈ, . . .	. . . . .	1070 ; 1222 ; 1318 ; 1580 + 1 ; *1601* ; 1642 + 3 ; 1671 ; 1690 ; 1735 + 3 ; 1755 + 3 ; 1756 E.–W. + 3 ; 1759 ; 1760 ; 1767 ; 1770 + 2 ; 1788 + 3 ; 1828 ; 1841 ; *1846* N.–S. ; 1851 ; 1868 + 2 ; 1869 + 2 S.W.–N.E. + 3 ; 1873 ; 1877 N.E.–S.W. ; 1878 + 1 S.S.W.–N.N.E. + 2 ; 1879 + 1 ; 1881 W.S.W.–E.N.E.	56
COLOGNY, . . .	Geneva, ...	1856 W.–E. + 3.	4
COLOMBIÈRES, . .	Neuchatel C., Switzerland, .	1756 E.–W. + 2.	3
COLOMIERS, . . .	Haute Garonne, . . .	1854 N.–S.	1
COLONNA, LA, . .	Roman States, . . .	1855.	1
COLONSAY HOUSE, .	. . . . .	1880.	1
COLORNO, . . .	Parma, ...	1857.	1
COLOSSA, . . .	Phrygia, ...	B. C. 58.	1
COL SAN MARTINO, .	Treviso Province, . .	1859.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
COMAOCHIO, . . .	Ferrara, ...	1853.	1
COMBAI, ...	Treviso Province, . .	1859.	1
COMBUR, . . . near	Cattaro, Dalmatia, . .	1853.	1
COMLA, . . . near	Nice, ...	1854.	1
COMMERCY, . . .	Meuse, ...	(1828 + 1) S.–N.	2
COMMINGUES District,	Pyrénées, France, . .	1777.	1
COMO, ...	. . . . .	1851 + 1 ; 1855.	3
COMORN (Komorn), . .	Hungary, ...	*1763* + 90 + 12 + 2, felt simultaneously at Raab ; 1764 + 2 ; 1765 + 1 ; 1767 ; *1773 + 3* ; 1774 + 1 ; 1777 ; 1782 ; **1783** S.–N. + 12 + 19 ; 1784 + 5 ; 1785 ; 1786 + 2, extended from Upper Danube to the counties of Odenburg and Eisenburg, + 1 ; 1806 + 2 ; 1810 ; 1814 + 3 ; 1822 + 26 ; 1838 ; 1841 + 1 ; 1843 + 1 ; 1845 ; 1851 + 1 ; 1857 + 2 N.E.–S.W. + 3 + 1 N.–S. + 1 E.–W. + 2 S.E.–E. ; 1862 + 1 ; (1863 + 1) N.W.–S.E. ; 1866 + 5 ; 1875.	226
COMRIE, ...	Scotland, ...	1789 + 3 ; 1790 ; 1792 ; 1795 ; 1799 + 1 ; 1801 ; 1818 + 1 ; 1820 ; 1821 + *1* ; 1824 ; 1828 ; 1839 + 48 ; 1840 + 48 ; 1841 + 57 ; 1842 + 15 ; 1843 + 5 + 1, felt over surface of 100 miles square, + 6 ; 1844 + 19 ; 1845 + 6 ; 1846 + 3 ; 1847 + 6 + 2, extended to 7 miles distance ; 1848 + 3 ; 1851 + 2 ; 1857 ; 1864 + 1 ; 1867, reached Greenlooning, 12 miles W. ; 1869 ; (1870 + 1) E.–W., extended to Strowart and valley of Earn, to 10 miles distance ; 1875 + 2.	260
COMPIANO, . . .	Parma, ...	1832 + 5 ; 1835.	7
COMPTON, . . .	. . . . .	1868.	1
CONCENTAINA, . .	Valencia, Spain, . . .	1858.	1
CONDINO, . . .	Tyrol, ...	1868.	1
CONDOM, . . .	Gers, ...	1862.	1
CONDRIEU, . . .	Loire, ...	1857.	1
CONEGLIANO, . . .	Treviso Province, . .	1859 ; 1873.	2
CONFREVILLE, . near	Hâvre, ...	1833.	1
CONGLETON, . . .	. . . . .	1852.	1
CONI or CUNEO, . .	Piedmont, ...	1808 ; 1818 ; 1854 + 2 ; 1855 S.–N. ; 1858 E.–W. + 1 ; 1865 + 1 ; 1866 ; (1878 + 1) E.–W.	13
CONINGSBY, . . .	. . . . .	1818.	1
CONSTANCE, . . .	. . . . .	1048 ; 1062 ; 1092 ; 1295 ; 1356 ; 1533 ; 1670 ; 1720 ; 1729 ; 1837 + 1 ; 1851 ; 1855 ; 1880 S.–N. + 1 ; 1881.	16
CONSTANCE LAKE, or	Bodensee, ...	1851 ; 1881.	2
CONSTANTINE Province,	Algeria, ...	1758 + 1 ; 1862 + 3.	6
CONSTANTINE, . .	,, ...	1838 ; 1839 ; 1849 ; 1855 ; 1856 ; 1859 N.W.–S.E. + 1 ; 1860 ; (1861 + 2) N.W.–S.E. ; 1862 + 3 ; 1863 ; (1865 + 1) N.W.–S.W. ; 1871 + 3 N.W.–S.E. + 6 ; 1876.	29

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CONSTANTINOPLE, .	. . . . .	363; 382; 396 + 4, violent shocks for several days; 401, walls thrown down; 403; 427; *434*; 444 + 60, lasting for 4 months; 447; 450; 477; 487; 525; 533 + 20, lasted 40 days; 546; 548; 553; 554; 556; 557 + 1 + 3 + 10, continuous for 10 days; 558; 559, cupola of Saint Sophia destroyed; 560; 611; 677; 740; 789; 795; 815; 840; 858; 861; 862; 867 + 40, shocks for 40 days and nights; 975; 986; 1010 + 6, violent; 0311; 1032; 1037 + 3; 1038; 1039; 1041 + 1 + 60, lasted 4 months; 1064; 1082; 1296; 1332; 1344; 1346; 1489; 1490; 1507; 1508 + 20, shocks for 40 days; **1509** + 3; 1542, also in Tuscany; **1556**; 1569; 1571, R. = 4 miles; 1633; 1641; 1646; *1659*; 1667 + 1; *1668*; 1688; 1690; 1712 + 1; **1714**; 1719 + 6 + 15, continued for 30 days; 1720; 1724; 1725; 1729; 1737 + 4; 1752 + 1 + 13 N.W.–S.E., direction of Adrianople; *1754* E.–W. + 25; 1755 + 3; 1756 + 2; 1758; 1760; 1763 + 1; 1766 S.–N. + 23 + 1 S.–N. + 1 + 6 + 1, extended to Vienna, + 17; 1767 + 6; 1768 + 1; 1769; 1770 E.–W. + 1; 1772 + 1; 1778; 1779; 1783; 1790 + 1; 1791 + 3; 1795; 1800 + 3; 1802 + 1; (1803 + 3) N.–S.; 1805; (1811 + 5) S.–N.; 1819; (*1826* + 5) N.–S., simultaneously at Smyrna; 1829 + 1, extended to Salonica, + 1; 1834 + 1; 1835; (1838 + 1) N.–S. + 2 N.W.–S.W., 5 leagues radius, + 3; 1841 + 3; 1844; 1845 + 1; 1850 N.–S.; 1853; 1854 + 5; (1855 + 6) E.–W. + 4 S.E.–N.W. + 4 S.–N. + 30; 1856; 1857 + 5 + 1 N.–S. + 1 N.N.W.–S.S.E.; (1858 + 1) S.W.–N.E.; 1859 + 5 + 2 E. 6° N.–W. 6° S.; 1860 + 2 + 3 E.–W. + 3 N.–S.; 1862 E.–W. + 1 S.E.–N.W. + 2; 1863 + 3 N.E.–S.W.; 1864 + 1; 1865 + 1 N.W.–S.E. + 1; 1866 + 4; 1867 + 1 N.–S.; 1868 + 1 N.W.–S.E.; 1869 + 2; 1870; 1871; 1872 + 2; 1874 + 6; 1875; 1877; 1878 + 3; 1880.	625
CONTAINIZA, . . .	Croatia, ...	1861.	1
CONTALLURO, . .	Termini District, Sicily, .	1858.	1
CONTARSI, . . .	Calabria Ultra, . . .	1853.	1
CONVOICE, . . .	Scotland, ...	1845.	1
CONWAY, . . .	. . . . .	1780.	1
COPTHALL, . . .	. . . . .	1750.	1
COPENHAGEN, . .	. . . . .	1745; (1760 + 3) N.–S.; 1809; 1829; 1841; 1881 N.E.–S.W.	9
COPAIS LAKE, . .	Greece, ...	1853.	1
CORATO, ...	Bari Province, . . .	1851.	1
CORBEIL, ...	Sein et Oise, . . .	1775; 1827.	2
CORCIEUX, . . .	Vosges, ...	1851 S.W.–N.E.	1
CORCELLES, . . .	Switzerland, . . .	1852.	1
CORDELIO, . . .	Anatolia, ...	1880.	1
CORDOVA, ...	. . . . .	1356; 1357; 1755 + 1; 1822; 1858; 1860; 1863.	8
COREDO, ...	Tyrol, ...	1881.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CORFU ISLAND, . .	. . . . .	*1732*, the sea seemed to rise inside of Fort; 1745; 1756; 1773; 1786; 1809 + 3; (1819 + 1) S.–N.; 1844; 1846; 1848 + 1; 1856 + 1; 1857; (1858 + 3) N.E.–S.W. + 2; 1859; 1862 + 1; 1866; 1867 + 10 + 4 N.W.–S.E. + 2 N.E.–S.W. + 2 W.–E.; 1868 + 1; (1869 + 2) N.W.–S.E.; 1882.	53
CORINTH, . . .	Greece, ...	522; 1817; 1851; 1852; 1858 + 5; 1859; 1860 + 1; 1861 + 11; 1862 + 3; 1867; (1869 + 2) N.W.–S.E.; 1870 + 1 + 400; 1876 W.–E., extended to Athens, Eubea, and Volo, and to Cephalonia + 10; 1882.	447
CORINTH, Isthmus of, .	. . . . .	1861; *1870*, disastrous; multitude of crevasses formed, 5–6 feet broad + 407.	409
CORINTH, Gulf of, .	. . . . .	*1756 + 1.*	2
CORIGLIANO, . . .	Calabria Citra, ...	1824 + 3; 1825; 1870 + 1.	7
CORK, ...	Ireland, ...	1755; 1761; 1820; 1821, numerous and violent shocks; 1868.	5
CORLEONE, . . .	Sicily, ...	1845 + 6; 1876 + 2 + 100, continuous from 22nd September.	110
CORMONS, . . .	Görtz District, Carniola, .	1869 + 2; 1870 + 11; 1878.	16
CORMERY, . . .	Indre et Loire, . . .	1855.	1
CORNETO, . . .	Civita Vecchia, . . .	1819; 1869 + 2.	4
CORNWALL, . . .	. . . . .	1756; 1757; 1859.	3
CORPS, ...	Isère, ...	1808.	1
CORSANO-ALLA-VILLA,	Sienna, ...	1847 E.–W.	1
CORSCHENBROICH, .	Gladbach C., Rh. Prussia, .	1869 S.E.–N.W.	1
CORTONA, . . .	Perugia	1849.	1
CORUÑA, ...	. . . . .	1761; 1844 S.–N.; 1845 + 1.	4
CORVOL-L'ORGEUILLEUX,	Nièvre, ...	1874.	1
COS ISLAND, . . .	. . . . .	B. C. 10; A.D. 477; 560; **1491 + 2**, 5,000 people killed; 1843; 1864 + 1; **1863**.	10
COSENZA, . . .	Calabria, ...	1824 + 3; 1825; *1826* + 1; 1832; 1835; 1840; 1841; 1845 + 1; 1846 + 2; 1850 + 1; 1851 + 1; 1852 + 4 + 1 N.W–S.E.; 1853; 1854 + 43, extended from Reggio to Naples, + 1 + 12; 1855 + 20; 1856 + 10; 1857 + 4 + 2 E.–W.; 1858 E.–W. + 6; 1859 + 1; 1860 + 6; 1861 E.–W. + 8 + 1 E.–W.; 1863 + 5 + 1 W.–E. + 1 S.S.W.–N.N.E. + 2 E.–W.; 1864 + 1; 1865 + 2 + 1 E.–W.; 1866 + 1 + 1 E.–W.; 1867 N.–S. + 4; 1868 + 4; *1869 + 4*; 1870 + 10 + 1 + **1**, centre at Sila, the parts most shaken situated on the western slope of the Silani mountains, on a line joining Cellara, San Stefano, Longobuco, and Rossano, running S.W.–N.E., or rather the main shocks took place between two lines parallel to the direction mentioned, + 168; 1871 + 98 + 3 S.W.–N.W. + 2 S.E.–S.W. + 2 S.–N.W. + 4 N.W.–S.E. + 1 E.–W. + 3 N.E.–N.W. + 2 S.E.–N.W. + 1 S.–N.E. + 1 N.N.E.–S.S.W. + 2; 1872; 1881 + 1 + 1 S.–N., parallel to the axes of the mountain chain.	488
COSSOS ISLAND, . .	Grecian Archipelago, . .	1856.	1
COSTEINITZA, . .	Croatia	1861.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CÔTE D'OR Department,	. . . . .	1862 + 1 ; 1866.	3
COTTENTIN, . . .	Normandy, ...	1713.	1
COTRONE, . . .	Calabria, ...	1832 + 2 ; 1842 + 2 ; 1855 + 1 ; 1856 + 1 ; 1857 ; 1860 ; 1869.	13
COUCHES, . . .	Saône et Loire, . . .	1882.	1
COUCHY, ...	Burgundy, ...	1882.	1
COULOMB, ST., . .	. . . . .	1757.	1
COULOMMIERS, . .	Loir et Cher, . . .	1864.	1
COURSEILLES, . .	Calvados, ...	1847.	1
COUNTRY between Main River and Rhine, . . .		1756 + 1.	2
COURTRAI, . . .	W. Flanders, Belgium, .	1809.	1
COUTANIES, . . .	Manche, ...	1161 ; 1853 + 1 ; 1876.	4
COVE OF CORK, . .	Ireland, ...	1820.	1
COVELLA, . . .	Ebro Valley, Spain, . .	1817.	1
COVENTRY, . . .	. . . . .	1666.	1
CRACO, ...	Basilicata, ...	1836.	1
CRACOW, ...	. . . . .	(1785 + 2) W.–E. ; 1786 + 3 ; 1842.	8
CRANESORS, . . .	Sweden, ...	1845.	1
CRECCHIO, . . .	Abruzzi, ...	1881.	1
CREFELD, . . .	Rhenish Prussia, . . .	1878 ; 1881 + 1.	3
CREMA, ...	Lodi, ...	1781 E.–W. ; 1786 ; 1802.	3
CREMBLEPOINT, . .	. . . . .	1777.	1
CREMONA, . . .	. . . . .	1223 ; 1339 ; 1829 S.–N. + 1 ; 1851.	5
CRESPINO, . . .	Firenze, ...	1846 + 2.	3
CRESSIER, . . .	Neuchâtel Canton, . .	1856.	1
CREUSE Department, .	. . . . .	1838 + 1.	2
CREUTZNACH-LES BAINS,	Rhenish Prussia, . .	1846.	1
CREUZOT, LE, . .	Saône et Loire, . . .	1855.	1
CRICK, ...	. . . . .	1768.	1
CRICKHOWEL, . .	. . . . .	1853.	1
CRIEF, ...	Scotland, ...	1801 ; 1821 ; 1822 ; 1838 ; 1839 ; 1845.	6
CRIMEA, ...	. . . . .	1790 ; 1802 ; 1827 ; 1853 + 3 ; 1855 + 3 ; 1869.	12
CRISSOLO, . . .	Piedmont, ...	1808 ; 1874 ; 1881.	3
CROATIA, . . .	. . . . .	1556 ; *1836* + 6 + 4 ; 1840 ; 1876 + 1 ; 1881.	16
CROLSHEIM, . . near	Biberach, Wurtemberg, .	1852.	1
CRONSTADT, Port of, .	Russia, ...	1868.	1
CRONSTADT, . . .	Moldavia Frontier, . .	1778 ; 1838 + 1 ; 1854 + 3 ; 1855 ; 1862.	9
CROSCIA, ...	Calabria Citra, . . .	1836.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
CROUGHTON, . . .	. . . . .	1731.	1
CROV, ...	On the Moselle, . . .	1869 + 1.	2
CROYDON, . . .	. . . . .	1750.	1
CRUMBACH, . . .	Darmstadt, ...	1873 N.–S.	1
CSAKATURN, . . .	Styria, ...	1880.	1
CSAKOVA, . . .	Hungary, ...	1858 + 1.	2
CSEPI, ...	,, ...	1860.	1
CSIKLOVA, . . .	Istria, ...	1871 + 1.	2
CUCHENHEIM, . .	Rhine Valley, . . .	1869.	1
CUCIGLIANA, . . near	Pisa, ...	1848.	1
CUDILLERO, . . .	Nalon River, Asturias, .	*1861.*	1
CUENCA MOUNTAINS, .	. . . . .	1817.	1
CUEVAS, ...	Almeria Province, . .	1865.	1
CUEVAS, ...	Andalucia, ...	1863 + 132, extended from Las Cuevas to Motril and the Sierra Nevada, + 2; 1865 + 2.	138
CIUDADREAL, . .	. . . . .	1431.	1
CULLERA, . . .	Valencia, ...	1856.	1
CULLY, ...	Vaud Canton, . . .	1855 + 2.	3
CULMBACH, . . .	Bavaria, ...	1872.	1
CULOZ, ...	Ain, ...	1881.	1
CUMBERLAND, . .	. . . . .	1843.	1
,, . .	West part of, . . .	1879.	1
CURANGO, . . .	Belluno Ter., . . .	1873.	1
CURZOLA ISLAND, .	Dalmatia, ...	1837 E.–W.; 1843; 1855 + 4; 1856 N.E.–S.W. + 1; 1870.	10
CUSONE, ...	Novi, ...	1882.	1
CUTRO, ...	Calabria, ...	*1832,* completely destroyed.	1
CYCLADES, . . .	. . . . .	477.	1
CYDONIES, . . .	Asia Minor, ...	1867 + 51.	52
CYPARESSA, . . .	Peloponessus, . . .	1865; 1874.	2
CYPRUS ISLAND, . .	. . . . .	B.C. 26; 92; A.D. 26; 77; 1201; 1204 + 1; 1222; 1577 + 2; 1718; 1736; 1822 + 3; 1861 + 1; 1870.	20
CYTHIENNE, . . .	Morea, ...	1867 + 2.	3
CYZICUM, . . .	. . . . .	985; 1064.	2
CZAKATORN, . . .	Hungary, ...	1870.	1
CZAKWAR, . . .	,, ...	1810.	1
CZALOS PETRI, . .	,, ...	1869.	1
CZERNOWITZ, . .	Gallicia, Austria, . .	1822 + 1; 1829; 1868 E.–W. + 1 S.–N.; 1875.	6
CZEGLED, . . .	Hungary, ...	1870.	1
CZUCZA, ...	Kolos Com., Transylvania, .	1880 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
DAADEN, ...	Altenkirchen C., Rh. Prussia,	1869 + 1.	2
DACHENHAUSEN, . .	Hesse-Darmstadt, . .	1780.	1
DACHOWSK, . . .	Mouth of Sotscha R., Black Sea, Russia,	1869 + 6 ; 1870 S.W.–N.E.	8
DAGALA, ...	Etna, ...	1880 + 6.	7
DAHRA, LA, . . .	Coast of Algeria, . . .	1870.	1
DALARNE, or DALCARLIA,	Sweden, ...	1752 ; 1756 + 1.	3
DALHEIM, . . .	Luxembourg, . . .	1869.	1
DALIAS, ...	Almeria Province, . .	1863 + 1.	2
DALKEY, . . .	Dublin Co., . . .	1852.	1
DAMALLY, . . .	. . . . .	1880.	1
DALMATIA, . . .	. . . . .	1418 + 3 ; 1556 ; **1667** ; 1840 ; 1842 + 10 ; 1843 + 10, coast of ; 1844 + 24 ; 1850 ; 1868 + *1* + 2 ; 1876 + 4.	64
,, ...	Southern, ...	1876 + 3 ; 1881.	5
DALMATIE VILLAGE, .	Algeria, ...	1867 + 4.	5
DALTON, ...	. . . . .	1704 ; 1818.	2
DAMARAN, . . .	Gard, ...	1877.	1
DAMASCUS, . . .	. . . . .	992 ; *1092*, half the city ruined ; 1092 ; 1155 : 1858, violent ; 1183 ; **1640** ; **1759** + 3 + 3 ; 1760 + 1 ; 1822 + 3 ; **1836** ; 1856 ; 1870 W.–E. + 1 ; 1872.	25
DAMLOVGROD, . .	Montenegro, . . .	1880 + 2.	3
DAMODOSSOLA, . .	Piedmont, ...	1880 S.–N. + 1 ; 1881 + 2.	5
DAMPIERRE SUR VENGEANNE,	Côte d'Or, . . .	1853.	1
DAMPIERRE LES BOIS, .	Doubs, ...	1857.	1
DANCEVOIR, . . .	Haute Marne, . . .	1862 + 1.	1
DENMARK, . . .	. . . . .	1646 ; 1724 ; *1755.*	3
DANICHEN, . . .	Scotland, ...	1808.	1
DANNEMARIE, . .	Haut Rhin, ...	1835.	1
DANNING, . . .	Perthshire, ...	1809.	1
DANSTROP, . . .	Sweden, ...	1850.	1
DANUBE, LOWER BASIN OF,	. . . . .	1868 ; 1875 ; 1878 N.W.–S.E. ; 1879, extended over a great part of Southern Hungary, Transylvania, Moldavia, and Wallachia ; 1879 + *5*.	10
DARDANELLES, . .	. . . . .	1762 + 1 ; 1835 + 1 ; 1850 ; 1852 + 2 ; 1855 + 2 ; 1859 + 1 + 17 W.–E. ; 1860 ; 1863 W.–E. + 2 ; 1865 + 1 ; 1867 + 19 + 1 N.–S. + 3 ; 1870 + 1 + 1 N.E.–S.W. ; 1871 + 1 N.E.–S.W. ; 1874 ; 1880.	67
DA RIVA, . . . near	Trente, Tyrol, . . .	1856 S.–N.	1
DARGMES, . . .	Gamaches Cant., Somme, .	1882 N.W.–S.E.	1
DARELL PASS, . .	Caucasus, ...	734.	1
DARLINGTON, . .	. . . . .	1768.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
DARMSTADT,		1733; 1756; 1787; *1788* S.-N.; 1790; 1791; 1802; 1807; 1859; 1869, extended to the Rhine on the W., to Frankfort on the N., to the Mumbrigthal on the E., to Heidelberg on the S. + 45 S.-N. + 3 S.S.W.-N.N.E. + 2 S.W.-N.E. + 26; 1870 + 8; 1871 + 48; 1872 + 2; 1873 + 9 + 1 S.W.-N.E. + 2 W.-E.; 1874 + 2 S.W.-N.E. + 1 N.E.-S.W. + 1; 1876 + 1.	167
DARTFORD,		1827.	1
DARTMOOR,		1732; 1858 + 1.	3
DÄRSTETTEN,	Sommenthal, Wurtemberg,	1842 + 1; 1844; 1845.	4
DASKHOVKA,	Sotscha R. Mouth, Movilef, [Russia,	1869 + 6.	7
DATTENFELD,	Waldbroel C., Rh. Prussia,	1869 + 1.	2
DAVIDSCHLAG,	Upper Austria,	1867; 1868.	2
DAVOS,	Lower Engadine,	1880 + 1; 1882.	3
DAUPHINY,		1584; 1784.	2
DAUN,	Rhenish Prussia,	1869.	1
DAWLISH,		1865.	1
DAWAWAR,	Croatia,	(1876 + 1) S.E.-N.W.	2
DAX,	Landes,	1858.	1
DAXLANDEN,	Baden,	1880.	1
DEAL,		1691; 1692; 1756; 1831.	4
DEBRICZEN,	Hungary,	1829 + 5 E.-W. + 3; 1859; 1880 + 1.	12
DECKENHEIM,	Between Main and Neckar,	1787.	1
DEINAR,	Irak Arabi, Asiatic Turkey,	1007, 10,000 inhabitants perished, buried in ruins, and many more swallowed up.	1
DEKA,	Marmorash, Hungary,	1867 + 1.	2
DELEBO VILLAGE,	Sweden,	(1853 + 1) S.-N.	2
DELIJAN,	Erivan, Transcaucasia,	(1853 + 2) E.-W. + 2; (1861 + 3) E.-W.; 1868 + 1 S.-N. + 1.	12
DELIJI,	Oropus River, Greece,	1860 + 2.	3
DELIMERI,	Messinia Province, Greece,	1846.	1
DELITZSCH,	Saxony,	1715.	1
DELLE,	Haut Rhin,	1835.	1
DELLYS,	Algeria,	1866; 1867 N.E.-S.W.	2
DELOS ISLAND,		B.C. 486; 431.	2
DELPHI,		B.C. 282; A.D. 1860; 1865; 1866 + 2.	6
DELVINO,	Albania,	1851.	1
DEMONTE,	Cuneo, Piedmont,	1844 + 2; 1858.	4
DEMOTICKA,	Roumelia,	1859.	1
DENITZLI,	Meander Valley, Anatolia,	1862 + 1.	2
DENGEBY,	Hungary,	1829.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
DENBIGH, . . .	. . . . .	1780.	1
DEPARTMENTS DU MIDI,	France, ...	1854 + 7, focus in neighbourhood of Cauterets and Barèges.	8
DERBENT, . . .	Caucasus, ...	1849 + 1; 1850; 1851 E.–W. + 1 + 2 E.–W.; (1852 + 1) E.–W. + 1; 1853 + 4; 1855.	16
DERBY, ...	. . . . .	1084; 1777; 1816.	3
DERBYSHIRE, . .	. . . . .	1683.	1
DEZENZANO, . . .	Lago di Garda, . . .	1866; 1868.	2
DETENSTEIN, . . near	Brunecken, Tyrol, . .	1850.	1
DEUCHOZA, . . .	Barany Com., Hungary, .	(1861 + 2) N.–S.	3
DEURNE, ...	Antwerp Province, . .	1848.	1
DEUTSCHNEUREUTH, .	Middle Rhine Valley, . .	1880.	1
DEUTZ, ...	Cologne C., Rh. Prussia, .	1869; 1878 + 1.	3
DEVEISER, . . .	Barany Com., Hungary, .	1874.	1
DEZVIN VILLAGE, . .	Romaies-Volca D., Roumalia,	1874.	1
DIABLERETS HOTEL, .	Vaud Canton, . . .	1874 N.W.–S.E.	1
DIAKOVAR, . . .	Essek Com., Hungary, .	1959 + 2; 1859 + 23.	27
DIARKEBIR, . . .	Mesopotamia, . . .	1866, R. = 30 leagues; 1867, 16 villages and whole population swallowed up + 2; 1872; 1874 + 3.	9
DIE, ...	Drôme, ...	1835.	1
DIEDENBERGER, . .	. . . . .	1850.	1
DIEPENBECK, . . .	Belgium, ...	1865.	1
DIEBURG, . . .	Darmstadt, ...	1869 + 2.	3
DIEPPE, ...	Seine Inferieur, . . .	1756; 1769; *1829* + 3; 1845; 1878.	8
DIERDORF, . . .	Neuwied C., Rh. Prussia, .	1869 W.–E. + 5.	6
DIESLACKEN, . . .	. . . . .	1873 W.S.W.–E.N.E..	1
DIETZ, ...	Nassau, ...	1869 + 2 N.W.–S.E. + 1.	3
DIGNE, ...	Basses Alpes, . . .	1862; 1863 + 1 + 1 S.–N.; 1866 E.–W.; 1876.	6
DIJON, ...	Côte d'Or, ...	1755; 1780; 1783, limited by a line passing through Langres, Chatillon, Aignay le Duc, and Montbard; 1784; (1791 + 1) E.–W.; 1822; 1838 + 1; 1846; 1855 N.E.–S.W.; 1862 N.–S., more felt in the north of Department, along band running N.W.–S.E. from Grancy to Mirebeau which bounds the Departments of Haute Marne and Haute Saône + 1; 1866; 1880; 1882 S.–N.	16
DILL RIVER, COURSE OF,	Rhenish Prussia, . . .	1862 + 1.	2
DILLENBURG, . . .	Nassau, ...	1869 + 1 N.–S. + 2.	4
DILLINGEN, . . .	Bavaria, ...	1787; 1852.	2
DINAN, ...	Côtes du Nord, . . .	1804; 1842 E.–W.; 1847.	3
DINGWELL, . . .	. . . . .	1880.	1
DINKELSBÜHL, . .	Bavaria, ...	1861 + 3.	4
DINNHEIM, . . .	Hesse, ...	1845.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
DIPPOLDSWALDE, . .	Erzegbirge, Saxony, . .	1877.	1
DISSENTIS, . . .	Grisons, ...	1855 ; 1879 ; 1880 + 1.	4
DITTELSCHEIM, . .	. . . . .	1869 + 1.	2
DITTERSDORF, . .	Silesia, ...	1799.	1
DIVERSDORF, . . .	Swabia, ...	1786 + 3.	4
DJEBEL-BELLOUT, .	Algeria, ...	1850 + 6.	7
DJELFA, ...	Algeria, ...	1867.	1
DJEMORAH, . . near	Biskra, Algeria, . . .	1869 + 1.	2
DJIDJELLI, . . .	Algeria, ...	1856 + 58 ; 1859 ; 1861 + 2 ; 1862 W.–E. + 1 N.–S. ; 1864 ; 1866 ; 1867 S.–N. ; 1876.	69
DOBRIKAU, . . .	Bohemia, ...	1858.	1
DOBNITZA, . . .	Rumelia, ...	1866 E.–W.	1
DOEHOBYCZOW, . .	N.-E. Gallicia, . . .	1875.	1
DOEUEN, ...	Upper Carinthia, . . .	1867 + 3.	4
DOGLIANI, . . .	Piedmont, ...	1866 ; 1868.	2
DOGNEN, ...	N. Flank of Pyrénées, .	1817.	1
DOGODOTSH, . . .	Armenia, ...	1134., the city ruined.	1
DOGOLA, ...	Sicily, ...	1868.	1
DOL, ...	Ille et Vilaine, . . .	1773 + 1.	2
DÔLE, ...	Jura, ...	1841.	1
DOLHAIN, . . .	Belgium, ...	1873.	1
DÖLLACH, . . .	Carinthia, ...	1862.	1
DOLUS, ...	Indre et Loire, . . .	1855.	1
DOMEZAIN, . . .	Basses Pyrénées, . . .	1843.	1
DONAU ESCHINGEN, .	Baden, ...	1858 + 2.	3
DONAUWERTH, . .	Bavaria, ...	1670 ; **1755** + 1.	3
DONCASTER, . . .	. . . . .	1792 ; 1816 ; 1863 ; 1871 ; 1873.	5
DONEGAL, Northern part of,	. . . . .	1840.	1
DONNEMARIE, . .	Seine et Marne, . . .	(1841 + 2) S.–N.	3
DONNICI, ...	Calabria Citra, . . .	1854.	1
DONOWITZ, . . .	Styria, ...	1880 S.–N.	1
DONSBACH, . . .	. . . . .	1869 + 1.	2
DONZÈRE, . . .	Drôme, ...	1859 ; 1873 + 2.	4
DORA BALTEA Valley, .	. . . . .	1880.	1
DORA RIPERIA, . .	Piedmont, ...	1874.	1
DORCHESTER, . .	. . . . .	1863.	1
DORDRECHT = DORT, .	Netherlands, . . .	1828.	1
DORES, ...	Scotland, ...	1817 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
DORKIN, ...	Surrey, ...	1551.	1
DORMAGEN, . . .	Neuss Canton, Rh. Prussia, .	1869.	1
DORNBACH, . . .	Illyria, ...	1869.	1
DORNDIEL, . . .	. . . . .	1873 S.W.–N.E.	1
DORNEEKDORF, . .	Solothorn Canton, . .	(1837 + 1) N.–S.	2
DORNEGG, . . near	Feitzitz, Carniola, . .	1870 + 8 S.S.W.–N.N.E. + 12 ; (1874 + 1) S.–N. + 1.	23
DORNHEIM, . . .	Sturkenburg Prov., Hesse, .	1869.	1
DORNSTETTEN, . .	Würtemberg, . . .	1843 ; 1844 + 3.	5
DORSETSHIRE, . .	. . . . .	1750 ; 1853.	2
DORSETSHIRE COAST, .	. . . . .	1839.	1
DORTMUND, . . .	Westphalia, ...	1874 + 2 ; 1876 ; 1878 + 3 ; 1880 S.E.–N.W.	9
DOTLA, . . . near	Schemakha, Caucasus, . .	**1669**, town destroyed, 8000 inhabitants killed.	1
DOTTINGEN, . . .	Würtemberg, . . .	1856.	1
DOTZHEIM, . . .	Wiesbaden, ...	1880.	1
DOUAI, ...	. . . . .	1866 E.–W.	1
DOUANNE, . . .	Berne Canton, . . .	1882 + 1.	2
DOUBS Department, .	. . . . .	1851 ; 1862 + 1 ; 1877.	4
DOUE, ...	Haute Loire, . . .	1855.	1
DOUERA = DOUEIRA, .	Algeria, ...	1847 ; 1850 ; (1867 + 3) S.–N.	6
DOVER, ...	. . . . .	1580 ; 1692 ; 1756 ; 1776 ; 1831.	5
DOWN, ...	Scotland, ...	1821.	1
DOWNING, . . .	. . . . .	1775 ; 1780 + 1.	3
DRA-EL-MIZAN, . .	Algeria, ...	1867 S.–N. ; 1877 + 1.	3
DRAGOMESTE, . .	Greece, ...	1867.	1
DRAGUINAN, . . .	Var, ...	(*1818 + 1*) N.W.–S.E. ; (1854 + 2) N.–S. ; 1858 E.–W. + 2 ; 1861 S.–N. ; 1866 N.–S.	10
DRAMA, ...	Macedonia, ...	1859 ; 1867 + 2.	4
DRAMNEN, . . .	Norway, ...	1834 ; 1865 + 1.	3
DREMADES, . . .	Albania, ...	1858.	1
DRENKOVA, . . .	Croatia, ...	1879 + 21.	22
DRESDEN, . . .	. . . . .	1763 + 1 ; 1857 ; 1862 + 5 ; 1869 ; 1872.	11
DREWSTEIGSTON, . .	Dartmoor, ...	1858.	1
DRIN, ...	Dalmatia, ...	(1871 + 1) S.E.–N.W.	2
DROH, . . . near	Briskra, Algeria, . . .	1869 + 1.	2
DRÔME Department, .	. . . . .	1873 ; 1877, part of.	2
DRONERO, . . .	Piedmont, ...	1851.	1
DRONTHEIM, . . .	Norway, ...	1690 ; 1799 ; 1819 + 1 ; 1834 + 1 ; 1863 ; 1866 S.W–N.E.	8
DRONTHEIM, Islands south of,	. . . . .	1834.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
DRUITS, ...	Ashburton, ...	1858.	1
DSCHEBRAIL, . . .	Elizabethpol Gov., . .	1868.	1
DSCHENGINSK, . .	Caucasus, ...	1869.	1
DSCHOBANY, . . .	Caucasus, ...	1869.	1
DUBITZA, ...	Croatia, ...	(1862 + 2) S.–N.	3
DUBLIN, ...	Ireland, ...	1690 : 1786 + 1 ; 1852 ; 1863.	5
DUBNO, ...	Volhynia, ...	1790.	1
DUBOSSAR, . . .	Crimea, ...	1821 + 1 ; 1824 + 1 ; 1829.	5
DUCLAIR, . . .	Eure, ...	1863.	1
DUDDINGTON, . .	. . . . .	1844.	1
DUDLEY, ...	. . . . .	1857.	1
DUISBURG, . . .	Rhenish Prussia, . . .	1881 W.–E.	1
DULKEN, ...	Kempen Canton, Rh. Prussia,	1869 E.–W. + 1.	2
DUMBARTON, . . .	. . . . .	1755 ; 1820.	2
DUMBLANE, . . .	. . . . .	1842.	1
DUMFRIES, . . .	. . . . .	1828 ; 1843.	2
DUNDRY, ...	Somerset, ...	1852.	1
DUNKELD, . . .	Scotland, ...	1822.	1
DUNKIRK, . . .	W. Flanders, Belgium, .	1671 ; 1828.	2
DUNSTON, . . .	. . . . .	1822.	1
DUPERRE Village, . .	Algeria, ...	1867.	1
DURA, ... near	Tripolis, Greece, . . .	1880.	1
DURANCE, Littoral de la,	France, ...	1863.	1
DURAZZO, . . .	Albania, ...	342, town destroyed ; 1273 ; 1869 + 1 ; 1871 W.–E. ;	5
DÜREN, ...	Rhenish Prussia, . . .	1756 ; 1868 ; 1876 ; 1878 + 7 ; 1881.	12
DURHAM, ...	. . . . .	1179 ; 1866.	2
DURKHEIM, . . .	Bavaria, ...	1869 + 3 S.–N. + 4 S.S.W.–N.N.E. + 2 S.W.–N.E. + 2 ; 1873 + 2 ; 1880.	16
DURLACH, . . .	Baden, S.-W. Germany, .	*1771 + 1.*	2
DÜRRENBERG, . .	Saxony, Prussia, . . .	1828.	1
DÜRRWEIN, . . .	Vienna District, . . .	1875.	1
DUSCHET, . . .	Tiflis, Transcaucasia, . .	1868 ; 1869 + 2 ; 1870.	5
DÜSSELDORF, . . .	Rhenish Prussia, . . .	1673 ; 1807 + 1 ; 1809 + 1 ; 1828 + 1 ; 1868 ; 1869 S.–N., the extreme points were Dusseldorf, Boppart, Eitdorf, and Hennif, Cuchenheim near Enskerchen ; 1878 + 2 ; 1881 + 1.	14
DUVANI Island, . .	50 versts from Bakou, Caspian,	1857.	1
DZOUNSOVASI, . near	Smyrna, ...	1867 E.–W.	1
DYRACHIUM, . . .	. . . . .	344 ; 352.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
EARRAID, . . .	. . . . .	1880.	1
EASTON, ...	. . . . .	1844.	1
EASTERN PYRENEES, Department of, ...		1824 ; 1837.	2
EAUX CHAUDES, . .	Basses Pyrénées, . . .	1800 + 2 ; 1862.	4
EAUX BONNES, . .	Basses Pyrénées, . . .	1843 ; 1847 + 1 + 2 E.–W. ; 1854 S.S.E.–N.N.W. ; 1874 W.–E.	7
EBERBACH, . . .	Baden, S.-W. Germany, .	1872 + 1.	2
EBERNDORF, . . .	Carinthia, ...	1857 W.–E.	1
EBERSTADT, . . .	. . . . .	1869 + 6.	7
EBERSTEIN, . . .	Carinthia, ...	1825 ; 1879.	2
EBERTZLINGEN, . near	Wurtzburg, ...	1607.	1
EBIGEWALD, . . .	Tyrol, ...	1851.	1
EBNAT, ...	Appenzall C., Switzerland, .	1881.	1
EBOLI, ...	Calabria Ultra, . . .	1853.	1
EBRO River, . . .	. . . . .	1817.	1
ECHALLENS, . . .	Vaud Canton, Switzerland, .	1846 + 1.	2
ECHARIX, . . .	Basses Pyrénées, . . .	1860 S.E.–N.W. + 1.	2
ECHEROLES, . . .	Isère, ...	1858.	1
ECHINGEN, . . .	Wurtemberg, . . .	1846 ; 1851.	2
ECHZELL, . . .	Darmstadt, ...	1873 + 1 W.–E.	2
ECKELL, ...	Schutt Island, Danube, .	1877 + 1.	2
ECLÉPENS, . . .	Vaud Canton, . . .	1882.	1
EDD = EID, . . .	Red Sea Coast, . . .	1861, "Volcanic eruption and fall of dust."—*Peterman's Nut. Geol.*, 1861, IX., p. 348.	1
EDENBRIDGE, . . .	. . . . .	1758.	1
EDIGER, ...	Moselthale, ...	1869 + 1.	2
EDINBURGH, . . .	. . . . .	1789 ; 1801.	2
EDIPSO, ...	Negroport, ...	1859.	1
EDSBERG, . . .	Norway, ...	1787.	1
EGER, ...	Bohemia, ...	1552 ; 1784 ; 1801 ; 1805 ; 1824 ; 1860, also at Reuth and Virtsberg, + 2 ; 1862 ; 1869 + 1 ; 1872.	12
EGERSUND, . . .	Norway, ...	1774 ; 1863.	2
EGERZEG, . . .	Agram District, Croatia, .	1880.	1
EGHEGIK Valley, . .	Caucasus, ...	700.	1
EGINA, ...	Greece, ...	1830 + 3.	4
EGLISAU, . . .	Zurich Canton, Switzerland,	1666 + 8 ; 1672 ; 1705 + 4 ; 1714 + 1 ; 1716 ; 1717 + 2 ; 1718 + 3 ; 1720 ; 1723 ; 1725 ; 1726 + 1 ; 1728 ; 1785 ; 1807 ; 1824 ; 1830 + 1 ; 1835 ; 1836 ; 1837 + 2 ; 1838 ; 1841 + 1 + 1 ; 1845 ; 1846 ; 1854 ; 1857 ; 1860 + 1 ; 1870.	52

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
EGLINGEN, . . .	Würtemberg, . . .	1830.	1
EGRA, ...	Saxony, ...	1770.	1
EGRA, ...	W. of Spidberg, Norway, .	1786.	1
EGSETH = EGYEST, .	Sond-Mör, Norway, . .	1842.	1
EGYBAZA, . . .	Pesth Com., Hungary, . .	1863.	1
EGYPT, ...	. . . . .	553; 742; 883; 887; 965; 997; 1032; 1069; 1074; 1204; *1344* + 3: 1633 + 3; 1870.	19
EHNINGEN, . . .	Würtemberg, . . .	1861; 1874.	2
EHRENBERG, . . .	Styria, ...	1877.	1
EHRENBREITSTEIN, .	Coblentz C., Rh. Prussia, .	(1869 + 1) N.W.–S.E.	2
EHRESHOVEN, . .	Wipperfurth C., Rh. Prussia,	1869 + 2.	3
EHRINGSHAUSEN, . .	Wetzlar C., Rh. Prussia, .	1869.	1
EIDESKOG, . . .	Norway, ...	1844 + 1.	2
EIDSWOLD, . . .	Norway, ...	1834 + 1.	2
EINDHOVEN, . . .	Holland, ...	1843.	1
EINSIEDELN, . . .	Schwitz Canton, Switzerland,	1871.	1
EINZHEIM, . . .	Baden, ...	1822; 1869.	2
EISCHLER, . . .	Bavaria, ...	1769 + 1.	2
EISENACH, . . .	Thuringia, S.-W. Germany,	1368.	1
EISENARTZ, . . .	Styria, ...	1805 + 2; 1843; 1863 + 1; 1864 W.–E. + 2 W.–E.; 1874 E.–W.	10
EISENBURG Com., . .	Hungary, ...	1880.	1
EISENFELD, . . .	Werrabasin, . . .	1847.	1
EISENKAPPEL, . .	Carinthia, ...	1879 W.–E. + 3 + 1; 1881 W.–E.; 1882 + 1 + 1 N.–S.	9
EISEN-THORES, . .	Temeswar, Hungary, . .	1866.	1
EISENTRATTEN, . .	Gmund, Illyria, . . .	1869.	1
EISFELD, ...	Thuringerwald, . . .	1831.	1
EISLEBEN, . . .	Saxony, Prussia, . . .	1838.	1
EITDORF, . . .	Sieg C., Rh. Prussia, . .	1869.	1
EITLITZ, ...	Bohemia, ...	1862.	1
EITRITSCH, . . .	Upper Saxony, . . .	1821.	1
EKATERINODAR, . .	Cossack Co., S.-W. Russia, .	*1799 + 1*, a new Island was formed in the sea of Azof opposite Temruck, 200 versts W. of Ekaterinodar.	2
EKATERINOGRAD, . .	Astrakan Russia, . . .	1861.	1
EKERSUND, . . .	Norway, ...	1863.	1
EL AFFROUN Village, .	Algeria, ...	1867 + 8; 1869.	10
ELBA ISLAND, . .	. . . . .	1846.	1
EL-BASSAN, . . .	Albania, ...	1851; 1860; (1864 + 1) N.–S.; 1870 + 4; 1871 + 4.	14

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ELBE RIVER, BASIN OF,		1553.	1
ELBE RIVER, LOWER COURSE OF,		1763 + 1.	2
ELBERMANNSTADT,	Oldenburg Duchy,	1626.	1
ELBERFELD,	Solengen C., Rh. Prussia,	1869.	1
ELBŒUF,	Eure,	1769; 1802; 1878.	3
ELBOGEN,	Bohemia,	1811; 1824; 1850 + 1 N.W.–S.E. + 2; 1862 N.N.W.–S.S.E.	7
ELCHE,	Alicante Prov., Spain,	(1854 + 1) S.W.–N.E.	2
EL HEBBAB,	Biskra Dist., Algeria,	1869.	1
ELIS,	Akarnania, Greece,	*1817 + 8*; 1861 + 1.	11
ELIZABETHPOL,	Caucasus,	1860, 20 versts to the S. of; 1861 + 2; 1863; 1867 + 2; 1870.	9
ELMEN,	Tyrol,	1879 S.–N.	1
ELMSHORN,	Denmark,	1755.	1
ELSA VALLEY,	Tuscany,	1804 + 4; 1838 + 3.	9
ELSDORF,	Station Neüss-Durren R.W.,	1878 + 20 + 1 S.–N.; 1879.	23
ELSTER,	[Rh. Peussia, Saxon Voigtland,	(1862 + 3) S.S.E.–N.N.W.	4
ELTHAM,		1750.	1
ELTITO,	Calabria,	1679.	1
ELTOILLE, ELFELD,	Nassau.	1861; 1869 + 3.	5
EL ZITO,	Basilicata,	1827.	1
ELY,	England,	1105.	1
ELY, COUNTY OF,		1165.	1
EMBRUN,	Hautes Alpes,	1780; 1808 S.S.W.–N.N.W.	2
EMD,	Valais,	1853.	1
EMRAENTHAL,		1839 N.W.–S.E. + 1.	2
EMMERICH,	Rhenish Prussia,	1878.	1
EMPTEN,	Bavaria,	1787.	1
EMS,	Nassau, S.W. Germany,	1846 + 1; 1869 + 1.	4
EMSWORTH,	England,	1824.	1
ENDRED,	Hungary,	1829.	1
ENGADINE, UP. AND LR.,		1622; 1651 + 4; 1827; 1832; (1839 + 1) N.W–S.E. 1856; 1860; 1861; 1868; 1878.	16
ENGADINE, UPPER,		1838.	1
ENGADINE, LOWER,		1813 + 1; 1882.	3
ENGERS,	Westphalia, Prussia,	1869 S.–N. + 1 S.W.–N.E. + 1.	3
ENGLAND,		974; 1043; 1076 + 3; 1081 + 1; 1085; 1089; 1090; 1099; 1117; 1119; 1153, very violent); 1185; 1186; 1199; 1246; 1274; 1275; 1284; 1382; 1385 + 1; 1426; 1580; 1661; 1692 + 1.	30

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ENGLAND, North of, .	. . . . .	1871 + 3; space shaken in a circle of which centre 2 miles E. of Sedbergh, Dumfries and Doncaster the limits N.W. and S.E.	4
,, Centre of, .	. . . . .	1863; 1864.	2
,, West of, .	. . . . .	1867.	1
,, S.-W. of, .	. . . . .	1868.	1
,, South of, .	. . . . .	1878.	1
ENGLISH CHANNEL, .	Coasts of, and of German Ocean,	1671.	1
ENINGEN, . . .	Würtemberg, . . .	1875.	1
ENNETMAAS, . . .	Unterwalden Canton, . .	1846 S.W.–N.E.	1
ENNISCORTHY, . .	. . . . .	1863.	1
ENOS, ...	Rumili, Turkey, . . .	1766; 1859 + 19; 1863; 1864 + 2.	25
ENSHEIM, . . near	Wörrstadt, Rh. Hesse, .	1869 E.S.E–W.N.W. + 4.	5
ENTLEBUCH, . . .	Lucerne Canton, . . .	1858; 1880 + 1.	3
EPINAL, ...	Vosges, ...	(1821 + 3) S.–N.; 1851.	5
EPIRUS, ...	Albania, ...	1807 "the most earthquaky country of Europe."—*Pouqueville;)* 1813; 1858 + 20; 1866.	24
,, N. and N.-W. of,	,, ...	1860.	1
EPPELSHEIM, . . .	Rhenish Hesse, . . .	1869 + 4.	5
EPPINGHOFEN, . .	Düsseldorf, Rh. Prussia, .	1857.	1
EPSOM, ...	. . . . .	1750.	1
EPPSTEIN, . . .	Nassau, ...	1728 + 3; 1788; 1858; 1869 + 1; 1878 + 3	12
ERBACH, ...	Darmstadt, Odenwald, . .	1855; 1856 + 3; 1869 + 3; 1873 + 3.	13
ERBSDORFERGRUND, .	. . . . .	1869.	1
ERFELDEN, . . .	Darmstadt, S.W. Germany, .	1869 + 7.	8
ERFURT, ...	Saxony, ...	1756; 1788 + 3.	5
ERGHENI, . . .	Albania, ...	1858, violent.	1
ERIVAN, Government, .	Armenia, ...	1840; 1846 + 1; 1869 S.W.–N.E.; 1871 + 3.	8
ERIVAN, Town, . .	,, ...	894, 20,000 lives lost; 1679 + 9, most violent for nine days.	11
ERLACH, ...	Berne Canton, . . .	1876.	1
ERLANGEN, . . .	Bavaria, ...	1852.	1
ERLAU, ...	Hungary, ...	1676; 1865 + 19.	21
ERLENBACH, . . .	Würtemberg, . . .	1856 + 4 + 2 S.–N.	7
ERZEROUM, . . .	Armenia, ...	*1784*, destructive; **1843** S.–N.; 1844 + 3; 1857 + 2; 1859 S.–N. + *2* S.W.–N.E. + 22, complete destruction of town, 4000 houses destroyed, 1500 lives lost, + 13 + 2 S.W.–N.E. + 31; 1860; 1861 + 10; 1868 + 6; 1871 + 3, extended over 200 leagues, followed uniformly a S.E.–N.W. direction from Bach-Kale towards Van; Bayazid and Mouch.	103
ERZGEBERGE, . . .	Saxony, ...	1539 + 1; 1540; 1552 + 3; 1701 + 3; 1720; 1756; 1784; 1824 + 7; 1852; 1856 S.W.–N.E.; 1857; 1862; 1866; 1877.	28

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ERZINGHAN,	Armenia,	(1867 + 3) E.–W. + 6.	10
ESCAWAR,	Hungary,	1811.	1
ESCHACH,	Würtemburg,	1852.	1
ESCHWEILER,	Rhenish Prussia,	1877 S.W.–N.E.; 1878 + 6; 1879 + 1; (1880 + 3) N.E.–S.W.	14
ESCOT VILLAGE,	Basses Pyrénées,	(1791 + 3) W.–E.	4
ESCURIAL,	Spain,	1755.	1
ESKAU,	Gothland,	1847.	1
ESKILSTUNA,	Sœdermanland, Sweden,	1801.	1
ESME,	Anatolia,	*1878*, town nearly destroyed.	1
ESSEG, OR OSJEK,	Sclavonia,	1857 + 1; 1859 S.E.–N.W. + 23; (1866 + 3) W.–E.; 1867 W.–E. + 2.	33
ESSEK,	Transylvania, Hungary,	1697 + 3; 1788 + 3; 1857 + 2; 1859 S.E.–N.W. + 21.	33
ESSENTOUXI,	Russia,	1866.	1
ESSLINGEN,	Würtemberg,	1871.	1
ESSORICE,	Seine et Oise,	1827.	1
ESTADINS, near	St. Béat, Haute Garonne,	1855.	1
ETANGS, LES,	Meurthe,	1846.	1
ETNA,		1633 + 1; 1651; 1669; 1688 + 7, shocks for 7 days; 1689; 1702; 1735, R = 30 miles; 1758; 1759; 1763, R = 30 miles + 1 + 1 + 1; 1780 + 1 N.–S. + 2; 1781; 1792; 1804; 1805; 1806 + 1; 1807 + 1; 1808 + 11; 1809 + 6; 1811; 1822 + 5; 1832 + 1 + 2; 1842; 1843; 1849; 1853; 1856; 1864 + 4; 1865 + 2; 1868 + 1; 1869 + 5; 1871; 1873 + 6; 1874 + 7; 1874, continuous; 1879 + 15; 1880 + 11; 1882 + 6.	136
ETSCH VALLEY,	Tyrol,	1880.	1
ETZDORF,	Upper Saxony,	1821.	1
EU,	Seine, Inferieure,	1882 N.W.–S.E.	1
EUBÆA ISLAND,		B.C. 426; 425; A.D. 1421 + 4; 1694; 1853; 1864 + 1; 1865 + 1; (1876 + 3) W.–E.	17
EUBÆAN GULF,		1853.	1
EUKRAINE, UKRAINE,	S.W. Russia,	1790, the district shaken limited by a line extending from Dubno in Volhynia in the N. to Brody and Lemberg in the W., to Hermannstadt and Schupfraneck in the Bannat and as far as Constantinople in the S. In the E. from Dubno to Berdiczew, Kew, Niemerow, Zulcain, Bender, Oczakow, Cherson; the Crimea, the most eastern point.	1
EUPEN,	Rhenish Prussia,	1873 + 1.	2
EUPHRATES,	Country between it and Tigris,	1866, R = 10 leagues; crevasses formed; 16 villages destroyed with all the inhabitants.	1
EURE DEPARTMENT,		1847.	1
EUROPE,		394; 395; 446; 543; 1000; 1081; 1085; 1289; 1290; 1349; 1545; *1601.*	13

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
EUSKIRCHEN,	Rhenish Prussia,	(1869 + 2) E.–W.	3
EVORA,	Portugal,	1757.	1
EVERTON, near	Liverpool,	1863.	1
EXETER,		1748 ; 1868.	2
EXETER County,		1866 + 1.	2
EYAM EDGE,		1755.	1
FABIANO,	Macerta,	1752.	1
FABOY,	Aisne,	1873 + 1.	2
FAENZA,	Ravenna,	1592 ; 1653 + 3 ; 1661 ; 1723 + 3 ; 1725 + 6 ; 1732 + 2 ; 1781 + 4 ; 1786 ; 1825 ; 1870 + 3 ; 1871 ; 1880 + 10 ; 1881.	44
FAGLIO Valley,	Romagna,	1881.	1
FAGOR, near	Gratz, Styria,	1852.	1
FAHAN,	Scotland,	1880.	1
FAHLUN,	Sweden,	1752.	1
FAIDO,	Tessin Canton,	1865.	1
FALAISE,	Calvados,	1775 ; 1853 + 1.	3
FALKENBERG,	Halland Province, Sweden,	*1786 + 3.*	4
FALKENAU	Fichtelgebirge, Bohemia,	1824 ; 1850 + 2 ; 1872.	5
FALKENSTEIN,	Erzgebirge,	1866 S.–N.	1
FÄLLENDEN,	Zurich Canton,	1861.	1
FALMOUTH,		1842 ; 1847 ; 1859 ; 1860.	4
FALSET,	Cataluña,	1845 + 3.	4
FALZE,	Treviso Province,	1859.	1
FANE, Parish of,	Bergen, Norway,	1851 S.E.–N.W.	1
FANGLIA,	Tuscany,	1846 + 1.	2
FANGO,	Ischia Island,	1881.	1
FANO,	Urbino e Pesaro,	1672 ; 1756 ; 1838 ; 1870 ; 1880.	5
FARNHURST,		1834.	1
FARO,	Portugal,	1856 + 5.	6
FAVIGNANA Island,	Sicily,	1823.	1
FAYS-BILLOT, LE, near	Bussyères, Haute Marne,	1850 + 2 ; 1862 + 2.	6
FÉCAMP,	Seine Inferieure,	1847 N.–S.	1
FEDIO,	Piedmont,	1858.	1
FEHRING,	Styria,	1865 + 1 + 1 N.W.–S.E.	3
FEISTRITZ,	Styria,	1849.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
FEISTRITZ, . . .	Carniola, ...	(1870 + 2) S.W.–N.E. + 5 S.S.W.–N.N.E. + 6 ; 1882.	15
FELDKIRCH, . . .	Vorarlberg, Tyrol, . .	1850 N.–S. ; 1852 ; 1869 ; 1875 ; 1878 S.–N. ; 1879 S.–N. ; 1880 N.E.–S.W. ; 1881 S.W.–N.E. + 1 S.E.–N.W. + 1 S.W.–N.E.	10
FELDBACH, . . .	Styria, ...	1862 + 3.	4
FELETTO, . . near	Conegliano, Venetia, . .	1873.	1
FELLA VALLEY, . .	Udine, ...	1876.	1
FELSBERG, . . .	Cassel, ...	1872 ; 1876.	2
FELSO-ST. GYORGY, .	Hungary, ...	1868 + 13.	14
FELSUND, . . .	Scandinavia, . . .	1866.	1
FELTRE, ...	Venetia, ...	1851 ; 1873.	2
FENESTRELLE, . .	Pinerolo, Italy, . . .	1808 + 3 ;	4
FERENTINO, . . .	Frozinone, ...	1880.	1
FERIZARU, . . .	Hungary, ...	1868 + 13.	14
FERLACH, . . .	Carinthia, ...	1840 ; 1855 W.–E. ; 1862 + 3.	6
FERMO, ...	Italy, ...	1871 ; 1881 N.–S. + 2.	4
FERRARA, . . .	. . . . .	1285 ; 1365 ; 1399 ; 1409 ; *1425* + 2 ; *1483* ; 1495 ; 1570 + 84 ; 1591 + 3 ; 1667 ; 1719 + 3 ; 1756 ; 1771 + 1 ; 1789 + 4 ; 1851 ; 1853 ; 1856 E.–W. ; 1869 ; 1870 ; 1880 + 1 ; (1881 + 1) S.E.–N.W.	120
FERRARA DI MONTI BALDO,	Verona, ...	1881 + 9.	10
FERRIERE, . . .	Parma Territory, . .	1840 + 1 ; 1845 + 1.	4
FERRIOLA VILLAGE, .	Lago Maggiore, . . .	1867 + 30, hot springs rose in several places.	31
FERRO D'ALPAGO, .	Belluno District, . . .	1873.	1
FERVENTO, . . .	Piedmont, ...	1880.	1
FESCHES-LE-CHATEL, .	Doubs, ...	1857.	1
FESCHES L'EGLISE, .	Doubs, ...	1857.	1
FETTAU, ...	Grisons, ...	1857.	1
FEUDENHEIM, . .	Manheim, Baden, . .	1873 + 1.	2
FEY, ...	Vaud Canton, . . .	1846.	1
FEZ, ...	Morocco, N. Africa, . .	1755 + 2 ; 1773.	4
FEZ, COAST OF, . .	,, ,, . .	1719.	1
FICHTELGEBIRGE, .	Bohemia, ...	1824 + 10 ; 1857 ; 1860.	13
FIDÉRIS, ...	Pratigau, Grisons, . .	1882 + 1.	2
FIGLINE, ...	Calabria, ...	1870 + 2 ; 1871.	4
FIGUERA, . . .	Portugal, ...	1858 + 1.	2
FILISUR, ...	Lower Engadine, . .	1880 + 1.	2
FILATTIERA, . . .	Massa e Carrara, . . .	1856 N.–S.	1
FINALE, ...	Emilia, ...	1871.	1
FINISTÈRE DEPARTMENT,	. . . . .	1829 + 3 others up to 1849.	4

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
FINLAND,	. . . . .	1751 + 4.	5
FIRENZUOLA,	Firenze, ...	1723 + 3; 1823; 1848; 1849; 1864 + 17; 1882.	26
FISCHENTHAL,	Himryl Dis., Zurich Cant.,	1881.	1
FIUME,	Croatia, ...	1776; 1785 + 4; (1802 + 3) N.–S.; 1838 + 4; 1845; 1846; 1853; 1854; 1855 + 1 + 1 E.–W.; 1857 + 1 + 1 E.–W.; 1860 + 3; (1866 + 2) N.N.W.–S.S.E. + 1 + 5 N.N.W.–S.S.E.; (1867 + 1) N.N.W.–S.S.E.; 1870 + 77 + 1 N.N.E.–S.S.W. + 30 N.W.–S.E. + 1 N.N.W.–S.S.E. + 7 N.E.–S.W.; 1879 N.E.–S.W. + 3; 1881 + 1 N.–S. + 1 E.–W.	164
FIVIZZANO,	Modena, ...	1481 + 15; 1767 + 35.	52
FLACHAN,	Saltzburg Alps, . . .	1787.	1
FLAMMERSFELD,	Altenkirchen C., Rh. Prussia,	1869 W.–E. + 2.	3
FLANDERS,	. . . . .	1382; 1449; 1530; 1531; 1692 + 1.	6
FLATTACH,	Upper Carinthia, . . .	1867 + 3.	4
FLATY Island,	Iceland, ...	1260.	1
FLAVIGNY,	Côte d'Or, ...	1755.	1
FLEETWOOD,	. . . . .	1852.	1
FLEKKEFIORD,	S.-W. point of Norway,	1786 + 2; 1875 + 3.	4
FLESCHOTTE, Vallée de	[Christiansund, la, Doubs, ...	1857, limited to a space 4 leagues × 2 leagues.	1
FLESSINGEN,	Holland, ...	1869 + 1.	2
FLIESS,	Tyrol, ...	1881 N.W.–S.E.	1
FLINT,	. . . . .	1780.	1
FLINTSHIRE,	. . . . .	1750.	1
FLISCH,	Göritz, ...	1871 N.E.–S.W.; 1876.	2
FLONHEIM,	Darmstadt, ...	1869 + 2.	3
FLORENCE,	. . . . .	1325; 1345 + 1; 1414 + 1; 1453 + 7; 1510; 1558; 1570 + 84; 1600 + 3; 1661; (1667 + 2) E.–W.; 1704; 1725 + 2; 1726; 1729 R. = 7 leagues; 1731; 1750, simultaneously in Calabria; 1751; 1757; 1762 + 11; 1764; 1765; 1768 + 2; 1769; *1770* + 2; 1771 + 1; 1777 + 1; 1781 + 2; 1783; 1786; 1787 + 3; 1789; 1796; 1798 + 3; 1804 + 2; 1810; 1812 + 6; 1814; 1825; 1828 + 1; 1835 + 2; 1837, extended to Genoa; 1839 S.–N. + 6; 1842 E.–W. + 2; 1843 + 3; 1844; 1845; 1846 + 1; 1847 + 2; 1849 + 2; 1851; 1853 + 1; 1854 + 3; 1858; 1864, centre at Firenzuola + 1 S.E.–N.W. + 5; 1865 + 2; 1866; 1867 + 1; 1869 N.–S. + 3 + 1 S.–N.; 1870 + 3; 1871 + 3 + 1 E.–W.; 1874 + 3; 1880 + 2 + 1 N.–S.; 1881 + 4.	249
FLÖRSHEIM,	Nassau, S.-W. Germany,	1850.	1
FLUSHING,	Zeeland, Netherlands,	1828.	1
FOCKSCHANG,	Wallachia, ...	1878; 1880 + 1.	3
FOERZBERG,	Transylvania, . . .	1855 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
FOGGIA,	Capitanata,	1730 + 49; *1739 + 2*, 3600 people killed; 1805; 1812; 1823 + *1*; 1851 + 2; 1852; 1853; 1854; 1858; 1864, extended from San Nicandro, + 1; 1866; 1875; 1881 N.–S.	69
FOGLIERI,	Archipelago,	1845.	1
FOHLRITZ, near	Zeilo, Gotha,	1869.	1
FOJANO DELLA CHIANA,	Arrezo, Tuscany,	1849 E.–W.	1
FÖLDRAR,	Transylvania,	1880.	1
FOLGOZA,	Portugal,	1856.	1
FOLIGNO,	Perugia,	1719; 1747; 1752; 1781; *1791* + 23; 1819 + 3; 1831 + 10; 1832 + 41; 1838 + 2; 1842; 1849 + 1; 1851 + 1; 1854 + 3; 1870 E. + 3; 1881 + 14, extended to Perugia + 2.	118
FOLLONICA,	Grossetto,	1850 + 3.	4
FONDO DI MACCHIA, near	Acireale, Sicily,	1855 + 8; 1865, most marked action in a longitudinal space running E. to W. from Fondo di Macchio to the sea 1 km. broad; extended to Cosenza in Calabria Citra, + 44; 1867.	55
FONTANA,	Terra di Lavoro,	1725 + 3.	4
FONTAINE-ARGENT, near	Besançon,	1851.	1
FONTAINE-FRANCAISE,	Côte d'Or,	1855 E.–W.; 1862.	2
FONTENAY LE COMTE,	Vendée,	(1864 + 2) W.–E.	3
FONTENAY, near	Montbard, Côte d'Or,	1855 + 2.	3
FONTCOUVERT,	Maurienne, Savoy,	1730; (1839 + 49) W.–E.	51
FOORD,	Scotland,	1880.	1
FOREZ,	Central France,	1877.	1
FORLACH,	Clagenfurth, Carinthia,	1830; 1857 W.–E.; 1865 + 3; 1879; 1882.	8
FORLI,		1429; 1661; 1725 + 3; 1732 + 2; 1778; 1781; 1813 + 16; 1828 + 17; 1843; 1844 + 9; 1861; 1863 + 1 + 2 N.–S.; 1865; 1866 + 1 + 1 S.–N.; (1869 + 2) S.–E.; (1870 + 1) W.–E. + 57; 1871 + 1; 1872; 1881 + 1.	133
FORLIMPOPOLI,	Forli,	1870 + 2; 1881.	4
FORNACETTA,	Tuscany,	*1740*.	1
FORNUORO,	Parma,	1831 + 3.	4
FORO,	Ischia Island,	1880 + 1.	2
FORSTAN,	Saltzbourg, Alps,	1786.	1
FORT DE JOUX,		1846.	1
FORTE DEI MARNEI,		1847.	1
FORTINO Mountains,		1881.	1
FORTIS,	Roman States,	1853.	1
FORT NAPOLEON,	Kabylie, Algeria,	1865 + 1; 1867 N.E.–S.W. + 1 + 1 N.–S.	5
FORT OPUS,	Dalmatia,	1834.	1
FORT WILLIAM,	Scotland,	1869; 1870; 1880.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
FOS,	Cataluña,	1853.	1
FOSSANO,	Piedmont,	1866; (1878 + 1) E.–W.	3
FOSSOMBRONE,	Urbino e Pesaro,	1865 + 2.	3
FOTH,	Pesth Com.,	1863.	1
FOZ,	Portugal,	1857.	1
FRAKOSTYAN,	Croatia,	1878 N.E.–S.W.	1
FRAMERSHEIM,	Rhine Hesse,	1874 E.–W.	1
FRANCE,		801; 849; 1289; 1382 + 1; **1394**; *1640 + 2*; 1692; 1756 S.E.–N.W.; 1822; 1866, extended over a polygonal surface of which Montbrison, Bordeaux, Nantes, Rouen, Tournus (Saône et Loire), Auxerre, Paris, the summits.	13
FRANCE,	Northern part of,	842; 843; 1640; 1828; 1881; 1882 N.W.–S.E.	6
,,	N.-W. part of,	1878, extended to England in the N., and to Tarbes in the S.	1
,,	S.-E. part of,	1855; 1881.	2
,,	Eastern,	1879.	1
,,	Western,	*1755*; 1799.	2
,,	Southern,	1588 + 3; 1750 + 7; *1755*; 1855 + 3; 1873.	18
,,	Central,	1841; 1881.	2
,,	West Coast of,	1660.	1
FRANCFORT VILBEL,	Darmstadt,	1869.	1
FRANCHE CÓMTE,		1218; 1755; 1757 + 3.	6
FRANCONIA,		1847.	1
FRANKENHAUSEN,	Rudolstadt, S.-W. Germany,	1873 + 1.	2
FRANKFURT ON THE MAIN,		1348; 1475; *1601*; 1640; 1642 + 3; 1653; 1655; 1668; 1681; 1682; 1691; 1692 + 1; 1693; 1703; 1704; 1707; 1727; 1728; 1733 + 2; 1735 + 3; 1787; 1788 + 4; 1799 + 1; 1828, extended over district between Frankfort and Mayence; 1829; 1846; 1868; 1869 + 15 + 3 S.S.W.–N.N.E.; 1871 + 1; 1872; 1873 + 2; 1874; 1878.	68
FRANZDORF,	Carniola,	1865; 1881 E.–W. + 1; 1882.	4
FRANZENBAD,	Bohemia,	1872.	1
FRANZENTHAL,	Hungary,	(1856 + 1) S.–N.	2
FRASCATI,		1695; 1750 + 1; 1754; *1773 + 3*; *1784 + 6*; 1785; 1791; 1801; 1811 + 1; 1816; 1817 + 1; 1818; (1819 + 1) S.E.–N.W.; 1821; 1833; 1836 + 1; 1837 + 2; (1855 + 2) N.N.W.–S.S.E. + 9 + *1*, June 29, extended to Rome, + 5; 1862; 1867 W.–E. + 2; 1870; 1873; 1880; 1881 + 1; 1882 + 2.	63
FRASIGLI,	Rome,	1752.	1
FRAUENFELD,	Thurgau,	1851; 1881 + 1.	3
FREDERICKSHANN,	Finland,	1855.	1
FREDERICKHOLM,	Sweden,	1874 W.–E.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
FREDERIKSWÄRK, .	Zealand, Denmark, . .	1866, between this and Gillelein, 30 miles from Copenhagen.	1
FREDERSDORF, . .	Silesia, ...	1799.	1
FREÏBERG, . . .	Saxony, ...	1552 + 1; 1720; 1764; 1768; 1829.	6
FREIBURG, . . in	Baden, ...	1829; (1830 + 3) S.W.–N.E.; 1841 + 2.	8
FREIWALDEN, . .	Silesia, ...	1878.	1
FREJENEDA, . . .	Salamanca, ...	1853.	1
FREUDENTHAL, . .	Carniola, ...	1881.	1
FREUDENSTADT, . .	Würtemberg, . . .	1855 + 2.	3
FRIBOURG, . . .	Canton of, ...	1755; 1877.	2
FRIBOURG, . . .	. . . . .	1509; 1617; 1823; 1827; 1830; 1831 + 2; *1836 + 2*; 1843; 1844; 1851; 1852; 1855; 1860 + 1; 1861; 1873; 1878; 1880 + 1 N.E.–S.W. + 3; 1881 + 1.	28
FRIBUS, ...	Bohemia, ...	1824.	1
FRICK, ...	Aargau, ...	1870.	1
FRIDECK, . . .	Silesia, ...	1785; 1786.	2
FRIEDBERG, . . .	Darmstadt, ...	1869 + 1 E.–W.	2
FRIEDLAND, . . .	Silesia, ...	1799.	1
FRIEDRICHSHAFEN, .	Lake Constance, . . .	1832; 1851.	2
FRIEDRICHSTAHL, .	Sweden, ...	1823.	1
FRIEDRICHSTHAL, .	Bohemia, ...	1858.	1
FRIESDORF, . . .	Bonn Circle, Rhenish Prussia,	1869.	1
FRIOUL, The, . . .	. . . . .	1715; 1776; 1788.	3
FRITH OF CLYDE, .	. . . . .	1871.	1
FROHNHAUSEN, . .	Fulda River, near Cassel, .	1869.	1
FRONTELLO, . . near	Mantua, ...	1752.	1
FROSINONE, . . .	. . . . .	1850; 1873; 1877.	3
FROSTEN, . . .	Norway, ...	1819.	1
FRUSHAM, . . .	North of Clodleigh, . .	1858.	1
FRÜTIGEN, . . .	Berne Canton, . . .	1620; 1726; 1729; 1839; 1880.	5
FUGEN, ...	Tyrol, ...	1860 + 1.	2
FULDA River, . . .	. . . . .	1767.	1
FULDERA, . . .	Grisons Canton, . . .	1871.	1
FULHAM, ...	. . . . .	1750.	1
FÜRFKIRCHEN, . .	Hungary, ...	1874; 1875; 1880 + 1.	4
FURFORT, . . .	Lahnthal, ...	1869 W.–E.	1
FURNESS, . . .	. . . . .	1865; 1867; 1871.	3
FURSTENAU, . . .	Onasbruck, Hanover, . .	*1784 + 1.*	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
FURSTENFELD, . .	Styria, ...	1865 N.–E. + 3 + 3 N.–S. + 1 N.W.–S.E.	8
FÜRTH, ...	Darmstadt, S.-W. Germany,	1869 + 4 ; 1873 + 2.	8
FURT, ...	Lower Austria, . . .	1873 ; 1874 N.E.–S.W.	2
FUSCARO, . . near	Norcia, Spoleto, . . .	1859.	1
FUSCALDO, . . .	Calabria, ...	1870.	1
FÜZITO, . . . near	Szony, Hungary, . .	(1866 + 1) W.–E. + 2.	4
GAAL, ...	Styria, ...	1864 + 1. N.–S.	2
GABAS, ...	Basses Pyrénées, . . .	1843 ; 1844 + 3.	5
GABBRO, ...	Pisa, ...	1846.	1
GABES, ...	Tunis, ...	1881, radius of 18 km. + 3 + 1 E.–W. + 240, strong shocks every hour for five days, + 3 radius of 55 km. + 1.	249
GABY, ...	North Italy, . . .	1880.	1
GACHNANG, . . near	Frauenfeld, Thurgau Canton,	1880 + 3.	4
GADMEN, ...	Berne Canton, . . .	1817.	1
GAETA, ...	Terra di Lavoro, . .	1875.	1
GAGGISBERG, between	Berne and Thun, . . .	1828 + 2.	3
GAGLIANO, . . .	Catania, Sicily, . . .	1822.	1
GAILLE, ...	Aveyron, ...	1855.	1
GAINSBOROUGH, . .	. . . . .	1777.	1
GAILLITZ Valley, . .	Carinthia, ...	1876.	1
GALATA, ...	Rumili, Turkey, . . .	1802 ; 1860.	2
GALATZ, ...	Moldavia, ...	1854 ; 1856 S.E.–N.W. + 5 ; 1859 + 1 ; 1860 ; 1876 N.–S. ; 1877 ; (1878 + 1) N.W.–S.E. + 1 ; 1880 + 1 ; 1881.	18
GALAXIDE, . . .	Corinth Gulf, . . .	1870.	1
GALGÓ, ...	Szolnok-Doboka C., Hungary,	1881.	1
GALEATA, . . .	Italy, ...	1393 + 3 ; 1828 + 17.	22
GALLICIA, . . .	Austria, ...	1786 ; 1816 ; 1838 + 1 ; 1845 ; 1851 ; 1858, extended over greater part of Moravia, Galicia, and Silesia. The surface shaken about 444 km. long from Breslau to Gran, and 333 km. broad from Ternow to Znaïm, Moravia.	7
,, ...	N.–E. part of . . .	1875 + 2.	3
,, ...	Eastern, ...	1881.	1
GALICIA, ...	Spain, ...	448 ; 455 ; 1816 + 2 ; 1845 + 1.	7
GALIGNANO, . . .	Terra di Otranto, . .	1870.	1
GALLIATE, . . .	Novara, ...	1393 ; 1828.	2
GALLICCHIO, . . .	Basilicata, ...	1857.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GALLIPOLI, . . .	Terra di Otranto, . .	1737 ; 1767.	2
GALLIPOLI, . . .	Rumili, Turkey in Europe, .	1766 ; 1846 + 1 ; 1847 + 1 ; 1850 ; 1852 ; 1855 + 4 ; 1859 + 7 + 3 S.W.–N.E. + 3 E.–W. ; 1860 + 1 S.E.–N.W. + 3 ; 1863 + 3 N.–S. + 1 E.–W. ; 1864 + 4 ; 1865 ; 1866 ; 1867 ; 1869 ; 1870 ; 1871 N.E.–S.W. ; 1881 + 5.	53
GALLIPOLI, . . .	Greece, ...	1866.	1
GALLNEUKIRCHEN, .	Upper Austria, . . .	1785 + 2 ; 1867 ; 1868 + 1 ; 1869 + 2.	9
GALLODORO, . . .	Messina, Sicily, . . .	1855.	1
GALLORO, . . .	Roman States, . . .	1855.	1
GAMSEN, ...	Valais Canton, . . .	1869.	1
GAMSTADT, . . .	Norway, ...	1875.	1
GAN, ...	2 leagues S. of Pau, Basses [Pyrénées,	1851.	1
GANDIA, ...	Valencia Prov., Spain, .	1863 S.–N.	1
GANGI, ...	Sicily, . . .	1822.	1
GANNAT, ...	Puy de Dôme, . . .	1838.	1
GANT, ...	Pyrénées, ...	1773 + 5.	6
GANZINGEN, . . .	Aargau Canton, . . .	1870.	1
GAP, ...	Dauphiny, H. Alpes, . .	1282 ; **1644** ; 1751 ; 1808 S.W.–N.E. + 1 ; 1866.	6
GARANCIA, . . .	Bosnia, ...	1880 S.W.–N.E.	1
GARDA, LAGO DI, . .	Venetia, ...	1864 ; 1866 + 3 ; 1868.	6
GARD DEPARTMENT, .	France, ...	1870 ; 1873.	2
GARDAGNA, . . .	Piedmont, ...	1845.	1
GARDIKI, ...	Epiris, ...	1858.	1
GARGANO Promontory, .	Capitanata, ...	1865 + 20 ; 1869 + 1.	23
GARIZOGLI, . . .	Messenia Province, Greece, .	1846.	1
GARMISCH, . . .	Bavarian and Austrian Frontr.	1864.	1
GARNAUKIRCHEN, . .	Upper Austria, . . .	1869 + 2.	3
GARONNE, R., Basin of,	. . . . .	1743 + 1.	2
GARSTANG, . . .	. . . . .	1871.	1
GARTEN MOUNTAIN, .	1 league from Berne, . .	1857.	1
GASAU, ...	Austria, ...	1868.	1
GASTEIG, . . . near	Gessenay Berne C., . .	1854 E.–W. + 1.	2
GASTEIN, BAD, . .	Saltzbourg C., Austria, .	1845 ; 1858 ; 1862.	3
GASTOUNI, . . .	Elis, Greece, . . .	1861.	1
GAUALGESHEIM, . .	Darmstadt, ...	1869 + 2.	3
GAVE VALLEY, . .	Basses Pyrénées, . . .	1852.	1
GAZA, ...	Palestine, ...	1032.	1
GBELLAN, . . .	Hungary, ...	1858 + 5.	6
GEBHARDSHAIN, . .	Altenkirchen C., Rh. Prussia,	1869.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GEBWEILER, . . .	Alsace, ...	1879.	1
GEDERN, ...	Darmstadt, ...	1869.	1
GEHREN, ...	Thuringerwald, . . .	1831.	1
GEIL VALLEY, . .	Carinthia, ...	1876.	1
GEILSDORF, . . near	Plauen, Saxony, . . .	1880.	1
GEISING, ...	Saxon Erzegebirge, . .	1877.	1
GEISLINGEN, . . .	Würtemberg, ...	1852 + 1.	2
GEISLINGER ALPS, .	,, ...	1861 ; 1868 + 1.	3
GEISHORN, . . .	Styria, ...	1864.	1
GELDERN PROVINCE, .	Holland, ...	1878.	1
GELENHAUSEN, . .	Cassel, S.W. Germany, .	1869.	1
GELESNOVODSK, . .	Russia, ...	1866.	1
GELIVARA, . . .	Swedish Lapland, . .	1852 N.E.–S.W.	1
GELOWINSK, . . .	Caucasus, ...	1870.	1
GELSDORF, . . .	Aarthal Coblentz C., . .	1869.	1
GEMEAUL, . . .	Côte d'Or, ...	1862.	1
GÉMÉNOS, . . near	Marseilles, ...	1846 + 1.	2
GEMLICK = GUEMLICK,	Anatolia, ...	1863.	1
GEMONA, . . .	Venetia, ...	1876 + 1.	2
GEMÜNDEN, . . .	10 miles from Gross Gerau, .	1869 + 8.	9
GENEREST, . . .	Nestur Canton, H. Pyrénées,	1870.	1
GENESSE, . . .	Seine et Oise, . . .	1841.	1
GENEVA, CANTON, .	. . . . .	1877 ; 1879.	2
,, LAKE, . .	. . . . .	1584 ; 1600 ; 1650 ; 1877 ; 1881 W.–E. + 2 + *5* N.N.E.–S.S.W., limits—Grenoble, Lyon, Macon, Mulhausen, Basle, Bern, Leuk, Chamounix, Aix.	12
,, ,, . .	Western shore, . . .	1881.	1
,, ,, . .	Southern shore, . . .	1881 + 2.	3
,, ,, . .	Northern shore, . . .	1881.	1
GENEVA, ...	. . . . .	1322 ; *1504* + 3 ; 1574 + 3 ; 1575 ; 1577 ; 1593 + 3 ; 1620 + 1 ; 1621 ; 1644 + 5 ; 1651 + 1 ; 1682 ; 1715 + 2 ; 1716 + 7 ; 1728 ; 1729 + 1 ; 1736 ; 1753 + 1 ; 1755 + 8 ; 1761 ; 1770 + 1, in two parallel directions from E. to W. ; 1788 + 1 ; 1802 ; 1808 ; 1817 + 1 ; 1822 ; 1825 ; 1836 ; 1837 + 1 ; 1839 + 1 ; 1841 + 2 S.W.–N.E. ; 1843 + 1 ; 1851 ; 1854 S.–N. + 1 ; 1855 + 7 + 1 W.–E. + 1 S.–N. : 1856 + 6 ; 1857 + 4 ; 1861 ; 1862 ; 1868 ; 1877 ; 1879 + 2 ; 1880 + 2, and along the lake, + 1 ; 1881 + 18 + 1, the centre in the Lower Rhone Valley ; 1882 + 2 + 1, extended to Grenoble, + 4.	138
GENEZZARO, . . .	Rome, ...	1844.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GENOA, ...	. . . . .	1217; 1276; 1688 + 1; 1689; 1703 + 1 N.–S.; 1720; 1730; 1732, felt at Leghorn and as far as Genoa; *1740*; 1741; 1742; *1751*, also felt about Milan + 1; 1753; (1756 + 1) S.–N.; 1765 + 2; 1767 + 4; 1768; 1772; 1775; 1780; 1800; 1807; 1810; 1812 + 1; 1818 + 4; 1819 + 2; 1825; 1828 + 2; 1831 E.–W. + 1; 1832 + 3; 1834; 1837; 1838; 1841 + 1; 1843; 1845; 1846; 1852 N.E.–S.W.; 1854 + 1 N.–S.; 1855 + 4 + 1 E.–W.; 1856 + 3; 1858 + 1 E.–W.; 1860 + 1; 1861 + 1; 1863 + 1; 1865; 1869 + 1; 1872.	86
GENOBITZ, . . .	Styria, ...	1865 W.–E.; 1868 S.–N.	2
GENSTÄTT, . . near	Naumberg, ...	1830 + 1.	2
GENZANO, . . .	Basilicata, ...	1752; 1799 + 3; 1817 + 1; 1829 + 15; 1855; 1869.	25
GEOKTCHEI, . . .	Bakou Gov, 97 versts from [Schemaka,	1867 + 1; 1868 N.E.–S.W. + 3.	6
GEORGIA, ...	Caucasus, ...	1841 + 7.	8
GEORGTSCHAU, . .	Caucasus, ...	1869.	1
GERA, ...	Saxony, ...	1857.	1
GERACE, ...	Calabria, Ult., . . .	1720; 1806; 1863.	3
GERMANY, ...	. . . . .	786; 801; 974; 1059; 1065; 1081; 1170; 1222; 1277; 1299; *1322*; **1394**; 1508 + 3; 1601; 1690; 1692; 1755, great earthquake of Lisbon; 1810; 1872 S.–N., greater axis of surface shaken E.N.E.–W.S.W., limits—Glogau, Berlin, Breslau, Hanover, Giessen, Wiesbaden, Stuttgard, Hechengen, Munich, Regenburg, Cham, Blatna, smaller ellipsoidal surface most shaken, axis N.N.E.–S.S.W.—limits: Leipzig, Jena, Radstadt, Lobenstein, Schneeberg in Fichtelgebirge and Eger.	22
,, . . .	Southern, ...	1117; 1871.	2
,, . . .	S. Western, . . .	1855; 1879 + 1.	3
,, . . .	N. Western, . . .	1878, extreme limits—Arnsberg and Hanover in the N., Offenbach and Michelstadt (Odenwald) in the S. W., Strasbourg, Paris, and Charleville in the S., and Liege and Brussels in the W., extended over a surface of 2000 square miles from Utrecht to Paris and from Hanover to the Odenwald.	1
GERMERSHEIM, . .	Bavaria, ...	1880.	1
GERNSHEIM, . . .	Hesse-Darmstadt, . .	1767; 1869 + 5; 1871 + 1; 1873 + 2.	12
GERONA, ...	Cataluña, Spain, . . .	1852 N.–S., and country towards Pyrénées + 3; (1868 + 1) E.–W.	6
GERS DEPARTMENT, .	France, ...	1867 W.–E.	1
GERRISGEIM, . . near	Dusseldorf, Rh. Prussia, .	1868 + 2.	3
GERVEY CHAMBERTON,	Côte d'Or, ...	1862 + 1.	2
GERVILLE, . . near	Fecamp, Seine Inf., . .	1847.	1
GESAL, ...	Styria, ...	1864.	1
GESSENAY, . . .	Berne Canton, . . .	1817 + 29; 1829; 1853 S.–N. + 1; (1856 + 1) S.–N.; 1867.	36
GESSO, ...	Abruzzi Citra, . . .	1863 N.–S.	1
GESSOPOLENA, . .	Abruzzi Citra, . . .	1859.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GEX,	Ain,	1846.	1
GHENT,	E. Flanders, Belgium,	1837 S.E.–N.W.	1
GHOR,	Gulf of El Lisan, Dead Sea,	1854.	1
GIARDINI,	Sicily,	1870.	1
GIARRE,	Etna, Sicily,	1865 + 2; 1868 + 1; 1869 + 1; 1870; 1881 + 2; 1879 + 7; 1880 + 3.	23
GIAURKÏO,	Anatolia,	1880.	1
GIAVENO,	Susa, Italy,	1881.	1
GIBRALTAR,		1750; 1755 + 4; 1768; 1773; 1776; 1834; 1838 + 6 + 2 E.–W.; 1868, the centre of action in the Straits, simultaneously with an eruption of Vesuvius, + 2 + 2 E.–W.; 1868 E.–W.; (1869 + 1) E.–W.	27
GICASTRO District,	Calabria,	1821 + 3.	4
GIELSDORF,	Bonn Cant., Rh. Prussia,	1869 N.W.–S.E.	1
GIESSEN,	Darmstadt,	1733; 1788 + 3; 1799 + 1; 1869 E.–W. + 3 + 1 S.W.–N.E. + 4; 1872; 1873.	18
GIGON,	Asturias,	1843.	1
GIGORS,	Drôme,	1856 + 1; 1866.	3
GILLENFELD,		1869 + 1.	2
GRIMAVA,	Albania,	1858.	1
GIMET,	Vaud Canton,	1882.	1
GINESTAS,	Cataluña,	1845 + 5.	6
GIOJA,	Basilicata,	1845.	1
GIOJA-FAURO,	Calabria,	1881.	1
GIOMRŒ,	Hungary,	1826.	1
GIORNICO, or IRNIS,	Ticinio Cant., Switzerland,	1832.	1
GIRGENTI,	Sicily,	1842; 1846, sea off.	2
GIROMANY,	Haut Rhin,	1843.	1
GIRONDE, LA,		1852.	1
GITSCH Valley,	Carinthia,	1876.	1
GIULLO NESSI, Commune,	Nap. Kg.,	1854 + 1.	2
GIUMARAENS,	Portugal,	1857.	1
GIVORS,	Rhône,	1855 N.–S.	1
GLAMORGANSHIRE,		1765; 1868.	2
GLARIS CANTON,		1573; 1594; 1654 + 14; 1661; 1663 + 4; 1665; 1668; 1870 + 1; 1673 + 3; 1674; 1679 + 3; 1681 + 3; 1682 + 1; **1684**; **1685**; 1687 + 1; 1701, thirty-seven shocks up to January 30, 1702; 1702 + 2; 1709 + 3; 1755; 1763; 1834; 1852; 1856 + 1; 1861.	98
GLARIS,		1856; 1868; 1871; 1875; 1877; 1879; 1881 + 2.	9

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GLASAU, ...	Upper Austria, . . .	1867.	1
GLASGOW, . . .	. . . . .	1755 ; 1756 ; 1786 ; 1801 ; 1821 ; 1839.	6
GLASNEVIN, . . .	Dublin County, . . .	1852.	1
GLATTFELDEN, . .	Zurich Canton, . . .	1726.	1
GLATZ, ...	Silesia, ...	1799, for the most part in a line from Glatz to Marklissa.	1
GLAVNICA, . . near	Agram, ...	1881.	1
GLEIS, . . . near	Gratz, Styria, . . .	1880 N.E.–S.W.	1
GLENGARRY, . . .	Scotland, ...	1833 ; 1839.	2
GLENAGEARY, . .	Dublin County, . . .	1852.	1
GLIATA, ...	Messenia Province, Greece, .	1846.	1
GLINA, ...	Illyria, ...	(1870 + 2) S.W.–N.E. + 3 ; 1881.	7
GLINJANVI-OSTROW =	Tunny Island, Caspian, .	1860, eruption of smoke and flame to a height of 350 feet above sea level.	1
GLION, ...	. . . . .	1879.	1
GLISS, ...	Valais Canton, . . .	1855 ; 1863 ; 1865 + 1 ; 1866 + 1.	6
GLOGAU, ...	. . . . .	1870 ; 1872.	2
GLOGGNITZ, . . .	Lower Austria, . . .	1862 E.–W. ; 1870 ; 1874 E.–W. ; 1879 ; 1880 S.–N. + 1.	6
GLOSSOP, . . .	Derbyshire, . . .	1755.	1
GLOTTERTHAL, . .	Fribourg in Bresgau, Baden,	1854.	1
GLOUCESTER, . . .	. . . . .	1574 ; 1768.	2
GLOUCESTERSHIRE, .	. . . . .	1812.	1
GLURNS, ...	Tyrol, . : . .	(1867 + 2) W.–E.	3
GMENDEN-FEURERA, .	Upper Austria, . . .	1865.	1
GMUND, ...	Illyria, ...	1869 S.W.–N.E. + 1 N.–S. ; (1881 + 3) S.–N.	6
GMUND, ...	Würtemberg, . . .	1861.	1
GMÜND	Carinthia, ...	1861.	1
GODDELAU, . . .	Starkenburg Prov., Hesse, .	1869 + 5.	6
GODERVILLE, . . .	Seine, Inferieure, . .	1847.	1
GODGARD, . . .	E. Gothland, Sweden, . .	(1783 + 2) E.–W.	3
GODESBERG, . . .	Bonn C., Rhenish Prussia, .	1869 + 1 ; 1878.	3
GODZO Island, . .	Malta, ...	*1846 + 1* ; 1855 ; 1856 + 1.	5
GŒPPINGEN, . . .	Würtemberg, . . .	1855 + 1 ; 1861.	3
GOGLAD, ...	Hungary, ...	1871.	1
GOITO, ...	Mantua, Italy, . . .	1851.	1
GOJAR, . . . near	Granada, Spain, . . .	1863.	1
GOLUBATZ, . . .	On the Danube, Servia, .	1881.	1
GOMBASSI, . . .	Florenec, Italy, . . .	1768 + 1.	2
GONDAR, ...	Ethiopa, ...	1853.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GONDOKORO,	White Nile,	1850, Loyack Mountain, lat. 41° 44′ N., long. 29° 20′ E, + 7 + 21; 1853 + 4; 1857, earthquakes frequent here, but feeble in effects.	35
GONOBITZ,	Styria,	1858; 1880.	2
GOODSHAUB, Colony,	Greenland,	1852.	1
GOODWOOD,		1734.	1
GORCUM,	Holland,	1843.	1
GORDES,	Vaucluse,	1803.	1
GORI,	Lat. 41° 56′, Long. 41° 46′, Caucasus.	1856 + 2; 1868.	4
GORING,	Sussex,	1734.	1
GORIATSCHEWODSK,	Caucasus,	1868.	1
GÖRITZ,	Austria,	1716; 1840; 1850 + 5; 1869 + 3; 1870 N.–S. + 25; 1873 S.E.–N.W. + 1 S.W.–N.E.; 1880 + 2 + 1 N.–S.	44
GORNJA,	Servia,	1881.	1
GOSPORT,		1811; 1834 + 1.	3
GOSSENGRUN,	Bohemia,	1824.	1
GÖSTRITZ,	Sommering, Carinthia,	1870 + 2 + 1 S.E.–N.W.	4
GOTHA,	Sweden,	1601; 1767.	2
GOTHA,	S.W. Germany,	1756.	1
GOTHENBURG,	Sweden,	1759 + 3; 1851 + 3 N.E.–S.W.	8
GOTHENBURG,	Denmark,	1829.	1
GOTHLAND, Eastern,	Sweden,	1810; 1847 + 1.	3
,, Western,	,, ,,	1847 + 1.	2
GOTSCHA LAKE,	Transcaucasia,	1852.	1
GOTTSCHEE,	Carniola,	1870 + 4; (1872 + 1) E.–W.; 1875 + 1; 1879 + 1 S.E.–N.W.; (1881 + 1) E.–W. + 2 N.E.–S.W.	15
GOTTESTHAL,	Carinthia,	1880 N.E.–S.W.	1
GOTHENHEIM,	Baden,	1882.	1
GOTTINGEN,	Germany,	1767; 1872.	2
GOTTLOT,	Servian Voywood,	1880.	1
GOULARDES,	Rhone Banks (Drome),	1873.	1
GOVI,	Tiflis, Caucasus,	1856 + 1.	2
GOVONE,	Piedmont,	(1878 + 1) E.–W.	2
GRABEN,	Baden,	1880; 1881.	2
GRABFELD,	Thuringia,	1847.	1
GRADAC,	Croatia,	1880 + 1 S.W.–N.E. + 1.	3
GRADATZ,	Bosnia,	1866; 1881.	2
GRADEDSKA,	Austria,	1784 + 3; 1858.	5
GRADESTIE,	Servia,	1881.	1
GRADIGNAN,	Gironde,	1852.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GRAFENHAUSEN,	Baden,	1787 + 6.	7
GRAFENSTEIN,	Carinthia,	1879 W.–E.	1
GRAHOVA,	Montenegro,	1880 + 1.	2
GRAISWODEN Valley,	near Grenoble,	1784 + 3 N.W.–S.E., extended from Grenoble to Chambery.	4
GRAMPIAN HILLS,		1819 ; 1846.	2
GRANAGLIONE,	Bologna,	1864.	1
GRAN,	Hungary,	1858.	1
GRANCY,	Côte d'Or,	1862.	1
GRANBRESSNITZ,	Schemnitz, Hungary,	1862.	1
GRANDCODÈRE,	Dordogne,	1856 N.–S.	1
GRAND CŒUR,	Savoy, France,	1852.	1
GRANDINA,	Portugal,	1858.	1
GRANDVILLE,	Manche,	1804 ; 1853.	2
GRÂNE,	Drôme	1865.	1
GRANGES,	Vaud Canton,	1881.	1
GRANDSON,	Vaud Canton,	1816 + *1*.	2
GRANZOY,	Deux Lèvres,	1866.	1
GRASLITZ,	Fichtelgebirge, Bohemia,	1824 + 1 ; 1860 + 1.	4
GRASSE,	Alpes Maritimes,	1767 + 2, felt more strongly at Nice, Genoa.	3
GRASSMORE,		1871 + 1 E.–W.	2
GRATZ = HRVDEC,	Styria,	1767 ; 1826 + 8, simultaneously at Admont ; 1829 ; 1830 S.E.–N.W. + 1 ; 1837 ; (1839 + 1) S.W.–N.E. ; 1841 N.–S. ; 1843 ; 1846 S.W.–N.E. + 2, extended from Murzzuschlag to Gratz ; 1850 + 3 ; 1863 + 1 ; 1865 ; 1880 + 2.	31
GRAVE,	N. Brabant, Netherlands,	1843 + 1.	2
CRAVENBROICH,	Rhenish Prussia,	1868 + 1 ; 1869.	3
GRAVESON,	Bouches du Rhône,	1863.	1
GRAVILLE,	Seine, Inferieure,	1847 ; 1848 N.W.–S.E., extended to Ingouville.	2
GRAVINA,	In Puglia, Terra di Barri,	1845.	1
GRAY,	Haute Saône,	1855 ; 1862.	2
GRAZALEMA,	Seville Prov., Spain,	1856 + 7.	8
GREAT BRITAIN,		1426.	1
GREAT MALVERN,		1868.	1
GRECIAN ISLANDS,		**1672**.	1
GREECE,		550 ; 552 ; 986 ; 1830 + 3 ; 1837 ; 1842 + 3 ; 1853 ; *1861* + 1, extended to the Peloponessus, Hellas and Zante, Athens and Eleusis ; 1870 + 1 + 31 ; 1864.	49
GREECE, Northern,		*1870* + 7.	8
GREENLAND,		1817.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GREENOCK, . . .	. . . . .	1755 ; 1821.	2
GREENWICH, . . .	. . . . .	1878.	1
GREIFENBERG, . .	Carinthia, ...	1855.	1
GREIFENSTEIN, . .	Wetzlar C., Rh. Prussia, .	1869 + 2.	3
GRENADA, . . .	Spain, ...	1431 ; 1523 ; 1778 + 3 ; 1785 ; 1804 + 4 ; 1806 + 1 ; 1822 ; 1824 + 7 ; 1826 + 30 ; 1829 + 6 + 1 ; 1836 + 1 ; 1846 1849 ; 1853 ; 1854 ; 1855 W.–E. + 1 ; 1856 + 8 + 1 N.–S. ; 1862 ; 1863 S.W.–N.E. + 2 + 1 S.W.–N.E. ; 1864 S.E.–N.W. + 3 ; 1868.	90
GRENADA, Kingdom of, .	Spain, ...	1680 + 3 ; 1804 + 4.	9
GRENCHEN, . . .	Solothorn Canton, . .	1881.	1
GRENOBLE, . . .	Isère, ...	1755 ; 1770 + 1 ; 1782 E.–W. + 2 ; 1783 ; 1784 + 1 ; (1785 + 1) N.–S. ; 1808 N.–S. + 1 ; 1809 ; 1839 E.–W. ; 1841 ; 1842 ; 1849 + 1 ; 1851 + 1 ; 1855 ; 1858 ; 1866 ; (1869 + 6) N.–S. ; 1881 + 6, extended from Lausanne + 1 ; 1882.	40
GRÉOULX, . . .	Basses Alpes, . . .	1862 + 1.	2
GRESTEN, . . .	Lower Austria, . . .	1856.	1
GRIES, ...	Tyrol, ...	1878.	1
GRIESHEIM, . . .	Darmstadt, ...	1790 + 2 ; 1859 + 3 ; 1869 + 2.	10
GRIGANTI, . . .	Principato Ultra, Italy, .	1787.	1
GRIGNON, . . .	Seine et Oise, . . .	1841 N.E.–S.W. ; 1852.	2
GRIGNONCOURT, . .	Vorges, 11 km. from Bourboune les Bains,	1861.	1
GRIGORIOPOL, . .	Cherson Gov., Russia, .	1847.	1
GRIMLINGHAUSEN, .	Neuss C., Rh. Prussia, .	1869.	1
GRIMONŒS, . . .	In Aarness-Syssel, Iceland, .	1706.	1
GRIMSEL MOUNTAINS,	Valais, ...	1817.	1
GRIMSTEAD, E., . .	. . . . .	1758.	1
GRENDENWALD, . .	. . . . .	1880.	1
GRIP, ...	Pyrénées, ...	1854.	1
GRISONS, . . .	. . . . .	1811 + 3 ; 1849 ; (1852 + 1) E.–W. ; 1861 ; 1862 ; 1871 ; 1881 + 2, first shock extended from Splügen to Chur and Filisur ; second shock from Magenfeld to Cauters, and from St. Bernhardin to Bergün.	13
GRISSHORN, . . .	Styria, ...	1864.	1
GRÆCHEN, . . .	Valais, ...	1855 ; *1856*, Dec. 8 ; 1857 + 59 ; 1858 + 94 ; 1859 + 66 ; 1860 + 42 ; 1861 + 34 ; 1862 + 33 ; 1863 + 38 ; 1864 + 4 ; 1866 + 2 ; 1867 + 7 ; 1868 + 10 ; 1869 + 4 ; 1870 + 13 ; 1871 + 8.	430
GRŒCHHEZBIEL, . .	Switzerland, . . .	1858.	1
GRŒDENTHAL, . .	Tyrol, ...	1865 + 2 ; 1869 + 2.	6

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GRONE,	Valais,	1882.	1
GROSBLIEDERSTROFF,	Sarre Valley,	1846.	1
GROS-NOJE FORT,	Kabarda, Transcaucasia,	(1868 + 1) S.W.–N.E.	2
GROSS-BIEBERAU,	Darmstadt,	1869 + 3.	4
GROSS-ENGSTINGEN,	Würtemberg,	1828.	1
GROSSETTO,	Tuscany,	1851; 1854 + 2 E.–W.	4
GROSS GERAU,	Hesse,	1869 + 10 + 1, felt at Darmstadt and at Langres + 5 + 1 + 6, extended to Marbourg in the W., + 291 + 3 + 10 W.–E. + 49 (vibrations); 1870 + 94 + 2 S.W.–N.E.; + 2, R. = 3 leagues, + 1 W.–E.; 1871 + 11; 1872; 1873 + 1; 1878 + 1. The surface of Gross Gerau proved by the Staff Engineering Officers to have sunk 2 inches.	493
GERAN (KLEIN),		1869; 1873.	2
GROSS HERMSDORF,	Saxony,	1832.	1
GROSS KANISCHA,	Hungary,	1810; 1842 + 3, R. = 7 leagues; 1876.	6
GROSS-KOSTELY = Krassova,	Hungary,	1828.	1
GROSS-ROHRHEIM, near	Darmstadt,	1869.	1
GROSS-SZENT MIKLOS,	Hungary,	1879.	1
GROSS SONTAG,	Styria,	1880 + 2.	3
GROSS WARDEIN,	(Nagy Varch), Hungary,	1880 + 1.	2
GROTTA-A-MARE,	Fermo,	1843.	1
GROTTO,	3 miles from Sienna,	1845.	1
GROTTA-FERRATA,	Rome,	1871.	1
GRUMELLO,	Bergamo,	1882.	1
GRÜNBACH,	Lower Austria,	1870 W.–E.	1
GRUNBERG MINE,	Saxony,	1860.	1
GRUNHEIM,	Saxon Voigtland,	(1862 + 1) S.W.–N.E.	2
GRUNINGEN,	Zurich,	1861 S.W.–N.E.	1
GRUYÈRE (HAUTE),	Fribourg,	1857.	1
GRYON,	Vaud Canton,	1874; 1881.	2
GSTAD,	Berne,	1881.	1
GSTEIG,	Berne,	1864.	1
GUAGLIETTA,	Naples Kingdom,	1853.	1
GUALDO,	Perugia,	1751 + 1; 1752.	3
GUARASI, near	Cefalu, Sicily,	1876.	1
GUARDA,	Engadine,	1860 + 2; 1861.	4
GUARDAMAR,	Valencia, Spain,	1828 + 11; 1829.	13
GUARDIA,	Calabria,	1857; 1865.	2
GUARDIA,	Acireale Dis., Sicily,	1880 + 1.	2
GUARDESTALLO,	Pisa,	1846 + 2; 1871 + 1.	5

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GUASTALLA, . . .	Modena, ...	1778; 1840 + 4; 1841; 1845 + 1; 1847; 1856 + 1 + 2 N.W.–S.E.; 1857 + 1; 1866.	17
GUBBIO, ...	Urbino e Pesaro, Italy, .	*1465* + 2; 1466 + 1; **1471** + 3; 1751; 1752; 1786 + 1; 1855, in prolongation of volcanic zone of Frascati.	14
GUBBINS, . . .	Southern Counties, England,	1750.	1
GUDAUR, . . .	Caucasus, ...	1871 + 2.	3
GUDOMAKER, . . .	,, ...	(1868 + 3) E.–W.	4
GUELMA, ...	Algeria, ...	1850 + 2; 1854 + 3; 1856 + 2; 1859; 1864; 1867 + 1.	14
GUENZET, . . .	Route de Selif à Bougie, [Algeria,	1850.	1
GUERANDE, . . .	Loire, Inferieure, . .	1819; 1840 E.–W.	2
GUERET, ...	Creuse, ...	1817; 1855 E.–W.; 1868; 1875 + 2.	6
GUERNSEY ISLAND, .	. . . . .	1750; 1761; 1843 + 1.	4
GUÉTHARY, . . .	Basses Pyrénées, . . .	1854 N.–S.	1
GUILER, . . . near	Brest, 3 leagues N.W. of, .	1849 + 2.	3
GUJA, ...	Treves Prov., . . .	1859.	1
GULBRINGE, SYSSEL, .	Iceland, ...	1240.	1
GULIER, ...	Pyrénées, ...	1852.	1
GULLBRANDSDALL, .	Hamar Prov., Norway, .	1834.	1
GULLIDSCHI, . . .	85 versts W. of Erivan, [Russian Armenia,	(1871 + 1.) N.W.–S.E.	2
GUMMERN, . . .	Carinthia, ...	1881 N.W.–S.E.	1
GUMMERSBACH, . .	Rhenish Prussia, . . .	1869 + 2 N.N.E.–S.S.W.	3
GUNDELFINGEN, . .	Baden, ...	1841 + 2.	3
GUNDERSHEIM, . .	Rhenish Hesse, . . .	1869 + 1.	2
GUNTERSBLUM, . .	Darmstadt, ...	1869 + 5.	6
GUNZBURG, . . .	Bavaria, ...	1769.	1
GURDIN, ...	Saône et Loire, . . .	1871.	1
GURGL, ...	Tyrol, ...	1858 + 1 N.–E.	2
GURK, ...	Carinthia, ...	1857 W.–E.; 1867.	2
GURKFELD, . . .	Carniola, ...	1880 + 5 S.E.–N.W.; (1881 + 2) N.W.–S.E.	9
GURTA, . . . near	Biskra, Southern Algeria, .	1869 + 1.	2
GUSDAL, ...	Christiania, Norway, . .	(1788 + 3) S.–N.	4
GUSS, ...	Upper Austria, . . .	1868 + 1; 1869 + 1.	4
GUSTAVSBURG, . .	Rhine Valley, . . .	1869 + 4.	5
GUSTENSTEIN, . .	Viennerwald, Austria, . .	1830.	1
GUTTERSLOHE, . .	Westphalia, . . .	1767.	1
GUULDALEN, PROVINCE,	Norway, ...	1344.	1
GUZEL HISSAR, . .	West coast, Anatolia, . .	1861 N.–S.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
GUZZANO, . . .	Emilia Prov., . . .	1880 + 2 S.–N.; 1881 + 1.	5
GWAR HARALD, . .	Gr. B., ...	1853.	1
GYERTYÁMOS, . .	Servian Voiwood, Austria, .	1879 + 1.	2
GYORIJIOS, . . .	Hungary, ...	1868 E.–W.	1
GYOROK, ...	12 miles E. by S. of Arad, [Hungary,	1874.	1
HAARLEM, . . .	Netherlands, . . .	1804; 1833.	2
HABKERN, . . .	Switzerland, . . .	1880.	1
HACKENBROISCH, . .	Neuss C., Rh. Prussia, .	1869.	2
HACKNEY, . . .	. . . . .	1750.	1
HADDERSLEBEN, . .	Denmark, ...	1882.	1
HAFODUNOS, . . .	. . . . .	1780.	1
HAGENEGG, . . .	Carinthia, ...	1880.	1
HAGENTHAL, . . .	Haut Rhin, . . .	(1844 + 3) W.–E.	4
HAGENAU, . . .	Alsace, ...	1577 + 3; *1601*; 1780; 1805 + 1.	8
HAGUE, The, . . .	. . . . .	1755; 1756; 1804.	3
HAIGER, ...	Nassau, ...	1869 + 1.	2
HAINAU, ...	Silesia, Prussia, . . .	1828.	1
HAINAULT, . . .	Belgium, ...	1714.	1
HAINDORF, . . .	Silesia, ...	1799.	1
HALBERG, . . .	Rhine Valley, . . .	1869 S.W.–N.E.	1
HALEDDI, . . near	Sinope, Black Sea, . .	*1880*, sank completely into the sea; no trace left.	1
HALIFAX, . . .	. . . . .	1738.	1
HALK-ADASSI, . .	10 leagues from Rhodes, .	1865.	1
HALL, ...	Tyrol, ...	1670; 1787; 1859; 1870 + 1; 1874; 1877; 1880 + 1.	9
HALLAND, . . .	Sweden, ...	1822 + 3.	4
HALLE, ...	Saxony, ...	1670; 1720; 1838.	3
HALLEN, ...	Tyrol, ...	1670, lasted several days; 1853; 1862.	3
HALLMANSŒCHT, . .	Upper Austria, . . .	1867; 1868.	2
HALLSBACH, . . .	Nerke Province, Sweden, .	1877, Rad. of 2 Swedish miles.	1
HALS, ...	Bavaria, ...	1858.	1
HALSENBACH, . .	Rhine Valley, . . .	1869 + 4.	5
HAM, ...	Somme, ...	1873.	1
HAMBURG, . . .	. . . . .	1699; (1760 + 3) N.–S.; 1824.	6
HAMELN, ...	Calenberg, Hanover, . .	1767.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
HAMM, ...	Altenkirchen C., Rh. Prussia,	1869 + 1.	2
HAMMA, ...	Algeria, ...	1849 + 1 ; 1850.	3
HAMMAN-RIVA, . near	Milianah, Algiers Prov., .	1856 S.E.–N, earthquakes frequent here, giving rise to thermal and sulphurous springs.	1
HAMMERDAL, . .	Jamtland, Sweden, . .	1750 N.E.–S.W, extended over a length of 8 miles.	1
HAMMERSTADT, . .	Bohemia, 40 miles S. by E. of [Prague,	1874 ; 1880 W.–E., extended to Klausenburg, Maros-Ludas, Debreczin, Gross Wardein, and Klein Köpisch.	2
HAMOUNA, . . .	Hungary, ...	1778 + 11 ; 1779.	3
HAMPSHIRE, . . .	. . . . .	1853.	1
HAMPSHIRE COAST, .	. . . . .	1834.	1
HANAU, ...	Cassel, S.W. Germany, .	1681 ; 1691 ; 1703 ; 1728 ; 1733 ; 1787 ; 1869 + 1 ; 1871.	9
HANBURY, . . .	Derbyshire, . . .	1678 E.–W.	1
HANDBOROUGH, Long, .	. . . . .	1683.	1
HANDEREY, . . .	S.W. Jutland, . . .	1865.	1
HANO, ...	Austria, ...	1843 + 4.	5
HANOVER, . . .	. . . . .	1767 ; 1872 ; 1878.	3
HANSDORF, . . .	Silesia, ...	1867 ; 1879 S.E.–N.W.	2
HAPARANDA, . . .	North Sweden, . . .	1882 N.E.–S.W. + 1.	2
HARANSCBER, . .	Croatia, ...	1881.	1
HARBOROUGH, . .	. . . . .	1776.	1
HARBURG, . . .	Bavaria, ...	1879 + 9.	10
HARDENBERG, . .	Overyssel, Netherlands, .	1869.	1
,, . . near	Durkheim, Bavaria, . .	1869 S.–N.	1
HARDANGER, Prefecture of,	Norway, . . .	1774 + 3 ; 1834.	5
HARDERWYCK, . .	Zuder Zee, Holland, . .	1781 ; 1824.	2
HARFLEUR, . . .	Seine, Inferieure, . .	1847 W.–E.	1
HÄRING, ...	Tyrol, ...	1879 + 1.	2
HARROWGATE, . .	. . . . .	1863.	1
HARSTOEFF, . . .	Halland Prov., Sweden, .	1766.	1
HARTBERG, . . .	Styria, ...	1865 + 3 + 1 N.W.–S.E.	5
HARTENBERG, . .	Elbogen C., Bohemia, . .	(1824 + 31) N.E.–S.W., the places mentioned, of which Hartenburg was apparently the centre of shock, lie nearly together in a line from N. E. to S. W. on the southern slope of the Erzgebirge Mountains.	32
HARTMANNSDORF, .	Saxon Voigtland, . .	1862.	1
HASSAN, ...	Bohemia, ...	1858, simultaneously at Waldmünchen, in Bavaria.	1
HASSAN-PACHA, . .	Messinia Prov., Greece, .	1846.	1
HASLINGDEN, . .	. . . . .	1869.	1
HASPARREN, Commune, .	Basses Pyrénées, . .	1864 S.–N.	1
HATFIELD, . . .	. . . . .	1750.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
HATTENHEIM, . .	Nassau, S.W. Germany, .	1869 + 3.	4
HATTERSHEIM, . .	Nassau, ...	1869.	1
HAUERSTEIN, . .	Baden, ...	1862.	1
HAUTE LOIRE, . .	. . . . .	1833 + 6.	7
HAUTE COUR, . .	Savoie, ...	1865.	1
HAUTE GARONNE, Department, ...		1854.	1
HAUTE MARNE, . ,,	. . . . .	*1862*, limits—Dancevoir, W.; Lure, E.; Chaumont, N.; Gevrey Chambestain, 10 km. south of Dijon, S.	1
HAUTES PYRÉNÉES, ,,	. . . . .	1854; 1868.	2
HAUTE SAÔNE, . .	. . . . .	1862.	1
HAUTE VILLE, . .	Yvetot Arrondissement, .	1845 E.–W.	1
HAVANT, ...	Hants, ...	1734; 1824.	2
HAVERHILL, ...	. . . . .	1869.	1
HÂVRE, ...	. . . . .	1671; 1757 + 1; 1772, 1775; 1847 W.–E.; 1853; (1855 + 3) S.–N.; 1878.	12
HAYFIELD, . . .	Sweden, ...	1818.	1
HAYLE, ...	. . . . .	1860.	1
HAYNINGEN, . . .	Swabian Alps, Würtemberg,	1830.	1
HEADINGLEY, . .	. . . . .	1871.	1
HEADLEY, . . .	. . . . .	1864.	1
HEBBENBRIDGE, . .	. . . . .	1864.	1
HECHINGEN, . . .	Würtemberg,. . . .	1855 + 2; 1868 + 1; 1872; 1875 S.W–.N.E.	7
HECLA VOL., . .	Iceland, ...	1300; 1693; 1754; 1810; 1846, R. = 7 leagues, + 1.	6
HEDDERNHEIM, . .	Darmstadt, ...	1869 E.–W.	1
HEDDERNSDORF, . .	Coblentz C., Rh. Prussia, .	1869 S.–N. + 1 + 1 S.–N.	3
HEIDELBERG, . .	Baden, ...	1789; 1822 + 1; 1869 + 11; 1871; 1873 + 5; 1874; 1878; 1880.	25
HEIDENHEIM, . .	Würtemberg, . . .	1861.	1
HEILIGENBERG, . near	Littau, Moravia, . . .	1863 + 2.	3
HEILIGENBERG, . near	Littai, Carniola, . . .	1882 + 1.	2
HEILIGENBLUTH, . .	Carinthia, ...	1862 E.–W. + 5 + 1 S.–N. + 2 S.–N.; 1881.	10
HEILBRONN, . . .	Würtemberg, . . .	1861; 1869 + 2; 1872 + 2.	7
HEIMRICHGRUN, . .	Bohemia, ...	1824 + 8.	9
HEINSBERG, . . .	Rhenish Prussia, . . .	1873.	1
HELENESDORF, . .	Caucasus, ...	1861 + 2; 1863; 1870 + 2 + 1 S.S.W.–N.N.E.	8
HELGOLAND, . . .	Norway, ...	1819.	1
HELIKE, ...	Peloponessus, . . .	B.C. 373.	1
HELIOPOLIS, . . .	Algeria, ...	1850.	1
HELIGOLAND, . .	Holstein, ...	1858.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
HELLESPONT, . .	. . . . .	B.C. 282; A.D. 368; 477; 1871, extended to Varna.	4
HELMSTADT, . . .	Baden, ...	1767.	1
HELSTON, . . .	Cornwall, ...	1842.	1
HELZWEILER, . .	Ahrweiler C., Rh. Prussia, .	1869.	1
HELSINGLAND, . .	Bothnia G., Sweden, . .	*1730.*	1
HEMBOURG, . . .	Gloucestershire, . . .	1852.	1
HEMNOES, . . .	Norway, ...	(1819 + 1) E.–W.; 1829 + 1.	4
HEMPSTEAD COURT, .	Gloucester, ...	1865.	1
HENDAYE, . . .	Basses Pyrénées, . . .	1841.	1
HENNEF, ...	On Sieg, ...	1869.	1
HEPPENHEIM, . .	Darmstadt, ...	1869.	1
HERBRIGGEN, . .	Valais, ...	1855 + 1.	2
HERCULANEUM, . .	. . . . .	A.D. 63; 1752; 1758.	3
HEREFORD, . . .	. . . . .	1574; 1853; 1868.	3
HEREFORDSHIRE, .	. . . . .	1755.	1
HERFORD, . . .	Westphalia, Prussia, . .	1767.	1
HERISEAU, . . .	Appenzell, ...	1826; 1880; 1881 + 2.	6
HERKULESBAD, . .	Croatia, ...	1881.	1
HERMAGER, . . .	Carinthia, ...	1876 + 1; 1882.	3
HERMANNSTADT, . .	Hungary, ...	1755; 1778 + 3; 1790; 1793; 1802; 1810 + 3; (1829 + 13) N.E.–S.W.; 1862 + 4; 1868 + 2; 1879 S.E.–N.W.; 1880 W.–E., extended to Debreczin, Gross Wardein, and Klein-Köpisch.	36
HERMUS, Plain of the .	Anatolia, ...	1880.	1
HERNE, ...	. . . . .	1843.	1
HERRENWIES = Herrenberg,	Schwartzwald, Würtemberg,	1880.	1
HERRENSTEIN, . .	Rhine Valley, . . .	1869.	1
HERSEL, ...	Bonn C., Rh. Prussia, . .	1856; 1869 + 1.	3
HERTFORD, . . .	. . . . .	1750.	1
HERTFORDSHIRE, . .	. . . . .	1755.	1
HERZEGOVINA, . .	. . . . .	1843 + 116; 1844 + 4; 1854 + 2; 1867 + 5.	131
HERZOGENRATH, . .	Rhenish Prussia, . . .	1873 + 5; 1874 N.W.–S.W. + 1; 1877 N.E.–S.W.; 1881.	10
HERZONGENBUCHSIE, .	Berne, ...	1881.	1
HESSE DUCHY, . .	. . . . .	1088; *1601*; 1793; 1871, limits—Saarbruck, Strasbourg, Esslingen, Stuttgard, Wiesbaden.	4
HESSE DARMSTADT, .	. . . . .	1869 + 2.	3
HETZDORF, . . .	Saxony, ...	1879.	1
HEUBACH, . . .	Odenwald, Würtemberg, .	1872 + 1.	2
HEUSDEN, . . .	Holland, ...	1843.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
HEUWEILER, . . .	. . . . .	1854.	1
HEVEHEGY, . . .	Hungary, ...	(1856 + 1) S.–N.	2
HIEFLAU, . . .	Bruck, Styria, . . .	(1830 + 2) N.E.–S.W.	3
HIEROPOLIS, . . .	. . . . .	58; 127; 494.	3
HIESZKA, . . .	Neusohl, Hungary, . .	1862.	1
HILBERSDORF, . near	Chemnitz, Saxony, . .	1862.	1
HILBURGHAUSEN, .	Meiningen, S.W. Germany, .	1831; 1847 N.–S.	2
HILDERSHEIM, . .	Hanover, ...	1869 + 3.	4
HILPERSDORF, . .	Illyria, ...	1869.	1
HILSENHAIN, . .	Western Odenwald, . .	1872 + 1.	2
HILTENSBERG, . .	Switzerland, . . .	1726.	1
HIMMELBERG, . .	Carinthia, ...	1881 S.W.–N.E.	1
HINTERBERG, . .	Styria, ...	1880.	1
HINTERPRATIGEN, .	Lower Engadine, . .	1882.	1
HINTERSTODER, . .	Lower Austria, . . .	1870.	1
HINTERSHEIM, . .	Grisons, ...	1880 + 2.	3
HINWYL, . . .	Zurich, ...	1861.	1
HINZENHEIM, . .	Rhine Valley, . . .	1869 + 1.	2
HIRSCHBERG, . .	Silesia, ...	1799 + 1.	2
HIRSCHSPRUNG, . .	Erzgebirge, Saxony, . .	1877.	1
HITTDORF, . . .	Solingen Cant., Rh. Prussia,	1869 N.W.–S.E.	1
HITTERDAL, . . .	Norway, ...	1834.	1
HIZAKOVER, . . .	in Mountains near Agram, .	1880.	1
HOBZELFINGEN, . .	Swabian Alps, Würtemberg,	1828.	1
HOCHHEIM, . . .	Hesse, Nassau, . . .	1869 + 4.	5
HÖCHST, ...	Darmstadt, ...	1869 S.–N. + 1 + 1 N.–S.; 1871 S.W.–N.E.	4
HODAIDA, . . .	Red Sea, ...	1861 + 3.	4
HŒKENSAIR, . . .	Skaraborg Prov., Sweden, .	1850, 3 leagues radius; numerous and strong shocks S.E.–N.W.	1
HOFHEIM, . . .	Hesse, Nassau, . . .	1869.	1
HOF MINE, . . .	Saxony, ...	1860.	1
HOHEN, . . between	Rhine and Sieg, . . .	1869.	1
HOHEN ASPERG, . .	Würtemberg, . . .	1869 + 2.	3
HOHENGEISSENBERG,	Bavaria, ...	1828.	1
HOHEN SAX, . . .	Zurich Canton, . . .	1672 + 1; 1674.	3
HOHENSÜLTZEN, . .	Rhine Valley, . . .	1869 W.–E.	1
HOHENWANG, . .	Mürzthal, Styria, . .	1876 S.S.W.–N.N.E.	1
HOHENZAU, . . .	Zurich Canton, . . .	1650 + 14; 1671 + 2.	18

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
HOHENZOLLERN, . .	Würtemberg, . . .	(1867 + 2) N.E.–S.W.	3
HOLBACH, . . .	Denmark, ...	1841.	1
HOLDERNESS, . .	. . . . .	1818.	1
HOLLAND, . . .	. . . . .	860, earth uplifted, one of the mouths of the Rhine closed; 1530; 1580; **1640** + 2; 1642 + 3; 1692, very widely extended, centre at Brabant, extended to Paris, Normandy, England, Flanders, Mayence, Frankfort, Valais, + 2, covered space of 2600 miles square; 1814;	14
HOLPE, ...	Waldbroel C., Rh. Prussia, .	1869 + 2.	3
HOLSTEINBORG District,	Iceland, ...	*1864*.	1
HOLYHEAD, . . .	. . . . .	1780 + 1; 1852.	3
HOLYWELL, . . .	. . . . .	1780.	1
HOLZBACH, . . .	Bohemia, ...	1824.	1
HOMBOC, ...	N.E. of Olmutz, Moravia, .	1858.	1
HOMBURG von der HÖHE,	Frankfort, ...	1855; (1869 + 3) S.S.W.–N.N.E. + 1; 1870; 1878.	8
HOMONNA, . . .	Hungary, ...	(1857 + 1) W.–E.	2
HOMOROD, . . .	Transylvania, . . .	1880 W.–E.	1
HONDA, LA, . . .	Constantine Prov., Algeria, .	1863, produced remarkable effects in the Artesian boring El Anatt (see *Comp. rend.*, Acad. Sci. France, t. LVIII. p. 115–116, 13th July, 1863).	1
HONFLEUR, . . .	Calvados, ...	1847; 1849.	2
HONNEF, ...	Cologne C., Rhenish Prussia,	1856 + 1; 1869 + 4.	7
HONTH, Comitat, . .	Hungary, ...	1851.	1
HOPE, ...	Lancashire, ...	1869.	1
HOPTON (E. Harling), .	. . . . .	1859.	1
HORB, ...	Würtemberg, . . .	1822; 1881.	2
HORGEN, ...	Zurich, Switzerland, . .	1861.	1
HORNBERG Mountains, 4	leagues from Eisenberg, Baden,	1850 + 1.	2
HŒRNISGRUNDEN, .	Schwartzwald, . . .	1880.	1
HÖRNOSAND, . . .	Wester Norrland, Sweden, .	*1718* + 21; 1744; 1745; 1747, extended along the coast for ten miles; 1752 + 3; 1761 + 2; 1776; 1845 + 3; 1857 S.E.–N.W.; 1878.	39
HORREM = HORRHEIM,	Würtemberg, . . .	1878.	1
HOROSKIO, . . .	Anatolia, ...	1880.	1
HORSHAM, . . .	. . . . .	1833.	1
HOSCHLITZ, . . near	Kremsis, Moravia, . .	1858.	1
HOSLAU, ...	Bohemia, ...	1858.	1
HOSPITAKA, . . .	Messenia Province, Greece, .	1846.	1
HOSTABRIET, Chateau de,	Cataluña, ...	1853.	1
HOULME, LE, . . .	Seine, Inférieure, . .	1769 + 1.	2
HRUBBRIEZONO, . .	Lublin District, Gallicia, .	1875.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
HUDDERSFIELD, . .	. . . . .	1863.	1
HUEDEN, ...	Styria, ...	1865.	1
HUELVA, ...	Spain, ...	1846 ; 1858 ; 1859.	3
HUERCAL OBRERO, .	Andalucia, Spain, . .	1863 + 432 ; 1864 + 3.	437
HULCRATH, . . .	Gravenbroich C., Rh. Prussia,	1869 S.–N.	1
HULL, ...	. . . . .	1704.	1
HUNGARY, . . .	. . . . .	518, the earth opened in many places 12 feet wide, and from some of the crevasses boiling water was given forth ; 1170 ; 1348 + 4, the earth opened in several places, a rain of blood is said to have fallen in several places ; 1443 ; 1552 ; 1590 ; 1676 ; 1721 ; 1763 ; 1766, on the frontiers ; 1777 ; 1783 + 1 ; 1784 + 3 ; 1786 + 1 ; 1810 + 1 ; 1835 ; 1838 + 5 ; 1841, extended from the Sea of Marmora to Altendorf in Gallicia ; 1856 ; 1864 S.E.–N.W. ; 1868 ; 1869 ; 1876.	38
,, SOUTHERN, .	. . . . .	1879.	1
,, ...	N.N.E. part of, . . .	1834 + 1.	2
,, ...	N.W. ,, . . .	1864.	1
HUNDSRÜCK MOUNTAINS,	Rhenish Prussia, . .	1565 + 3 ; *1788.*	5
HUNGEN, ...	Upper Hesse, . . .	1869 + 1.	2
HÜNINGEN, . . .	Baden, ...	1755 ; 1843 S.E.–N.W.	2
HUNTINGTON, . .	York, ...	1754.	1
HUNTERSTODER, . .	Bohemia, ...	1856 + 1.	2
HUSAVICK, . . .	Iceland, ...	1872 + 2.	3
HUSST = HUSZTH, . .	Marmaros Com., Hungary, .	(*1830* + *3*) N.–S. ; 1863 + 3.	8
HUTTELDORF, . .	Lower Austria, . . .	1875.	1
HUY, ...	Belgium, ...	1878.	1
HYDRA ISLAND, . .	Grecian Archipelago, . .	*1457* + 2 ; *1837*, centre of disturbance apparently at Methore, + *3* ; 1867.	8
HYERÈS ISLAND, . .	. . . . .	1708.	1
HYNISH, ...	Hebrides, ...	1880.	1
HYSKEIR, . . .	,, ...	1880.	1
IBBS, ...	Frontier of Bavaria and Tyrol,	1879.	1
ICELAND, . . .	. . . . .	1290 ; 1294 ; 1338 ; 1391 ; **1580**, continued from July to September ; 1619 ; 1707 ; 1755 ; 1766 ; 1775 ; 1785 ; 1786 ; 1799 + 1 ; 1808 ; 1814 ; 1818 ; 1821 ; 1823 + 1 ; 1825 + 1 ; 1847 ; 1868 + 2 ; 1870 ; 1873 ; 1874 + 34 ; 1875 + 14 ; 1879.	79
,, SOUTHERN, .	. . . . .	1161 ; 1164 ; 1165 ; 1219 ; 1339 ; 1344, the River Gund disappeared ; 1657 ; 1663, near Kriswick a lake disappeared ; 1825 + 3 ; 1829 ; 1862 + 2 ; 1868 + 15 ; 1870 + 2.	35

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ICELAND, Western, .	. . . . .	1345.	1
,, Northern, .	, ...	1726 + 3 ; 1814 ; 1874, continued shocks, + 10.	16
,, ...	Holsteinborg District, . .	1864.	1
ICNAZ, ...	. . . . .	1861.	1
IDICE Valley, . . .	Romagna, ...	1881.	1
IDRIA, ...	Carniola, ...	1855 ; 1856 ; 1870 + 1 + 3 s.w.–n.e. + 1 s.e.–n.w. ; 1879 + 1 n.e.–s.w. ; 1882.	11
IDSTEIN, . . near	Lœrrach, Nassau, . .	1869 + 4 ; 1878 + 1 ; 1879.	8
IENA, ...	Thuringia, ...	1785 ; 1872.	2
IFFIGHEIM, . . .	Bavaria, ...	1877.	1
IGLESIAS, . . .	Sardinia Island, . . .	1856 + 1.	2
IHOLDY, ...	Basses Pyrénées, . . .	1858.	1
ILANZ, ...	Grisons, ...	1880 + 2.	3
ILCHESTER, . . .	. . . . .	1726.	1
ILE DES PALMES, . .	Marmora Sea, . . .	1862.	1
ILE DIEU, . . .	Poitou, ...	1808.	1
ILLE, ...	E. Pyrénées, . . .	1797.	1
ILLE et VILAINE Department,	. . . . .	1843.	1
ILLIEZTHAL, . . .	Valais, ...	1869 + 1.	2
ILLNAU, ...	Zurich, ...	1861.	1
ILLYRIA, ...	. . . . .	*1563* ; 1840 ; 1868 ; 1870 + 3.	7
ILVIDESŒ, . . .	Norway, ...	1834 + 1 + *2*.	4
IMBROS ISLAND, . .	. . . . .	1859 + 22 w.–e. + 181, extended to Gallipoli, Dardanelles, Enos, Adrianople, Constantinople, Metylin, Arivali (Asiatic coast), Smyrna, Broussa, Sophia, Philipoli, Lemnos, Samothrake, and Tenedos—this area lies between 38° and 43° lat. N., and 20° and 28° long. E. from Paris—may be represented by a circle having for diameter the line joining Imbros to Adrianople (line of greatest intensity), another circle of less intensity passing through Sophia, + about 92.	296
IMMENDORF, . . .	Rhenish Prussia, . . .	1873.	1
IMMERATH, Immigrath,	,, ,, . .	1869.	1
IMOLA, ...	Ravenna, ...	1732 + 2 ; 1781 ; 1813 ; 1853 ; 1854 ; 1861 ; 1870 + 1.	10
IMOSCHI, . . .	Dalmatia, ...	1877.	1
IMPENSCHITZ, . .	Croatia, ...	1812.	1
IMST, ...	Tyrol, ...	1850 w.–e. ; 1851 e.–w.	2
INCHOLA, . . .	. . . . .	1855 + 4 ; 1856 + 4.	10
INDEN, ...	Juliers C., Rhenish Prussia,	1869 e.–w.	1
INDRE, Department, .	. . . . .	1841 + 1.	2
INDSHA, ...	Russian Armenia, . .	1871.	1
INEBOLI, ...	Northern Asia Minor, . .	1865 + 5 n.–s.	6

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
INGELHEIM, . . .	Darmstadt, ...	1869 + 1.	2
INGOLDSTADT, . .	Bavaria, ...	1755 + 1.	2
INGOUVILLE, COMMUNE, .	Near Hâvre, . . .	1847 W.–E. ; 1848 ; (1855 + 3) S.–N.	6
INNER VILLGRATEN,	Austria, ...	1855 N.–S.	1
INNISHOWEN, BARONY, .	County Donegal, . . .	1841.	1
INNSPRUCK = INSPRUCK,	Tyrol, Austria, . . .	1571 ; 1572 + 3 ; 1667 + 3 ; 1670 E.–W., lasted several days ; 1671 ; *1689 + 1* ; 1787 S.W.–N.E. ; 1794 ; 1805 ; 1810 ; 1812 ; (1814 + 1) W.–E. ; 1817 ; 1818 ; 1820 + 2 ; 1826 + 6 + 3 N.E.–S.W., extended to Zurich ; 1829 ; 1830 ; 1836 ; 1837 + 1 ; (1843 + 2) S.E.–N.W. ; 1847 + 1 ; 1852 + 2 + 1 N.W.–S.E. + 3 + 1 S.W.–N.E. ; 1856 ; 1860 + 1 ; 1861 + 2 ; 1862 + 6 + 2 S.–N. + 1 S.E.–N.W. ; 1863 W.–E. + 2 ; 1865 + 2 N.–S. ; 1868 + 1 ; 1869 + 3 ; 1870 + 2 ; 1871 ; 1872 + 4 + 3, extended from Matry to Landsbach ; 1873 ; 1874 + 5 ; 1876 + 3 ; 1877 ; 1878 + 3 ; 1879 ; 1880 + 1.	112
INTERLACHEN, . .	Berne, ...	1729 ; 1756 ; 1835 ; 1839 ; 1855 + 1 ; 1856 + 9 ; 1867 + 1 ; 1879.	19
INVERARY, . . .	. . . . .	1880.	1
INVERGELDY, . .	. . . . .	1843.	1
INVERHALLEN, . .	. . . . .	1756.	1
INVERNESS, . . .	. . . . .	1769 ; 1800 ; 1817 + 2 ; 1818 + 1 ; 1880.	8
IONA, ...	. . . . .	1880.	2
IONIAN ISLANDS, . .	. . . . .	1820 S.E.–N.W., Rad. of about 200 leagues, + 2 ; 1865 ; 1867, extended to Candia, Malta, and Sicily.	5
IRANIC, ...	Croatia, ...	(1870 + 1) S.E.–N.W.	2
IRAK, ...	Northern Persia, . . .	1204 ; **1755 + 1.**	3
IRELAND, WESTERN, .	. . . . .	1756.	1
IRHOLEZ, . . .	Marmoros Com., Hungary, .	1880 N.E.–S.W.	1
IRKUTSCH, . . .	Siberia, ...	*1769* S.–N. + *1* ; 1771 + **1** ; 1773 + 3, along the Altai Chain ; 1813 + 1 ; 1824 + 2 ; 1829 N.E.–S.W. + 28 ; (1839 + 2) N.W.–S.E. ; 1853 S.E. ; 1856 + 1 + 4 S.W.–N.E. ; 1857 + 1 ; 1858 ; 1862 + 21 ; 1863 ; 1865 + 5 ; 1866 + 1 ; 1867 + 1 ; 1868 E.–W. + 1 ; 1875.	91
IRSEE, ...	Bavaria, ...	1855 + 1.	2
IRTON, ...	. . . . .	1755.	1
ISBARTA, . . .	31° 31′ N. Lat., 28° 20′ E. Long., Asia Minor,	1862 + 3.	4
ISCHIA ISLAND, . .	. . . . .	1762 + 61 ; 1812 ; 1827 + 1 ; **1828** + 1 ; 1841 + 1 ; 1851, extended from Vultur Volcano and Basilicata ; 1852 + 1 ; 1863 + 1 + 1 E.–W. ; 1864 ; 1867 + 1 ; 1880 + 1 ; **1881**, destructive.	81
ISCHIKLI, . . .	Asia Minor, . . .	**1875**, destructive, several thousand houses and people destroyed.	1
ISCHL, . . . near	Lintz, Upper Austria, . .	1812 ; 1873 + 5.	7
ISÈRE, DEPARTMENT, .	. . . . .	1838 ; (1839 + 3) N.E.–S.W. ; 1877 ; 1881.	7

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ISERLOHN,	Westphalia,	1878.	1
ISERNIA,	Molise Province,	*1805*, town destroyed; 1826 + 3; 1865 + 1.	7
ISHEKLI,	Anatolia,	*1874*.	1
ISLAND GLASS,		1880.	1
ISLICKEN,	Thurgau Canton,	1880 + 3.	4
ISMAIL,	Moldavia,	1827 + 1; 1829 + 1; 1831 + 1; 1835, simultaneously at Kischenew; 1838 + 3; (1854 + 1) N.E.–S.W.	13
ISMAILA,	Egyyt,	(1870 + 2) E.–W.	3
ISMID,	Anatolia,	1878 + 1.	2
ISNY,	Würtemberg,	1851.	1
ISOLA,	Calabria, Terra di Lavoro,	1777; 1832; 1874 + 1.	4
ISPAHAN,	Persia,	**1844**, felt at 12 miles distance, extended into the Aderbaïdan and the Irak, covered a great space; **1853**, disastrous—10,000 people killed.	2
ISPARTA,	28° 30′ Long., 38° 31′ Lat., Asia Minor,	1861 + 1; 1862 + 5; 1863 + 3.	12
ISSENBERG = ISSEBURG,	Westphalia,	1869.	1
ISSOIRE,	Puy de Dôme,	1833 + 3; 1881.	5
ISSUM,	Geldern C., Rhenish Prussia,	1869.	1
IS-SUR-TILLY,	Côte d'Or,	1810.	1
ISTEIN, near	Lörrach, Baden,	1870 + 3.	4
ISTRIA,		1870 + 10; 1873.	12
ITALY,		B. C. *197* + 38, shocks continued for 38 days; A. D. **6**; 615; 707; 801; 844; 1040; **1118**; 1151 + 3, numerous and great shocks; 1155; 1259; 1278; 1300; 1317 + 1; 1348; 1382; 1385; 1490; 1508 + 3; 1510 + 3; 1533 + 3; 1542; *1673* + *2*; 1680; 1756; 1785 + 3; 1851; 1870.	86
ITALY, CENTRAL,		B. C. *221* + 56; A. D. 1661; **1754**; 1880; 1881.	61
,, SOUTHERN,		1348 + 8, lasted more than 8 days; 1870; 1875; 1882, centre at Isernia Abruzzi.	12
,, NORTHERN,		1802; 1826; 1834 + 1; 1836; 1853; 1872 + 1; 1874 S.W.–N.E. + 1 E.–W.; 1875; 1881.	12
ITEA,	Corinth Gulf,	1870.	1
ITHACA ISLAND,		1802; 1867 + 2; 1868.	5
ITTIRIDIO = ITERIDU,	Sardinia Island,	1870.	1
ITZETZINO,	Sparta, Greece,	1867.	1
IUANOWKA,	South Russia,	1829.	1
IVANGOROD,	Baltic Province, Russia,	1881 + 1.	2
IVANKA,	Uman Cir., Russia,	1880.	1
IVREA,	Italy,	1802 + 2; 1808 + 4; 1824 + 3; 1870 + 1; 1880 + 1; 1881.	17
IZAOUT,	Haute Garonne,	1835.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
JABLONTS, . . .	Presbourg Com., Hungary, .	1870.	1
JABRIKOWA, . . .	Neusohl, ,, .	1862.	1
JABURC, ...	Servia, six leagues from [Roudwek,	1854.	1
JACEA, ...	Aragon, Spain, . . .	1814, extended from Oleron.	1
JAEN, ...	Andalucia, ...	1712 + 15 ; 1847 + 1 ; 1860 + 1.	20
JAFFA, ...	Syria, ...	*1836* ; 1856 + 2.	4
JAKATERINOSLAW, .	Russia, ...	1829.	1
JALAI JARVI, . . .	E. Bothnia, Sweden, . .	1765.	1
JALBOVA, . between	Broussa and Constantinople,	1859.	1
JALTA, ...	Crimea, ...	1869.	1
JALZA, ...	N.W. Bosnia, . . .	1869.	1
JANDRENOUVILLE, .	Belgium, ...	1828.	1
JANDRIN, . . .	,, ...	1828.	1
JANINA, ...	Epirus, ...	*1740* + 9 ; 1807 + 15 ; 1808 + 1 ; 1809 + 3 ; 1810 + 1 ; 1811 + 3 ; 1812 + 1 ; 1813 + 19 ; 1814 + 4 ; 1815 + 8 ; 1851, extended from Janina to Delvino in the S., and to El Bassan in the N. ; (1856 + 11) S.E.–N.W. ; 1857 S.E.–N.W. + 4 + 2 S.–N. + 12 + 1 S.E.–N.W. ; (1858 + 2) N.–S. + 2 S.E.–N.W. + 3 S.W.–N.E. + 4 ; 1858 + 3 N.W.–S.E. ; 1859 S.E.–N.W., felt in all Epirus, + 6 S.–N. + 1 S.W.–N.E. + 1 N.E.–S.W. ; (1860 + 15) S.E.–N.W. + 2 ; 1866 + 1 ; 1867 + 2 ; 1876 + 4 ; 1881 + 6.	167
JAYZIC, LA, . . .	Hungary, ...	1868.	1
JANZÉ, ...	Ille et Vilaine, . . .	1843.	1
JAREMBINA, . . .	Hungary, ...	1881 + 1 W.–E.	2
JARRIER, . . .	Savoie, ...	1844.	1
JARRIS, ...	Isère, ...	1858.	1
JARVIS, ...	Carinthia, ...	1856 S.W.–N.W.	1
JASSY, ...	Moldavia, ...	(1681 + 3) E.–W. + 2 ; 1804 + 3 ; 1818 ; 1821 + 2 ; 1823 + 1 ; (1827 + 1) N.–S. ; (1829 + 3) W.–E. + *2* W.–E. ; 1838 + 1 ; 1843 + 1 ; 1857 ; 1861 + 1 ; 1872 ; 1875 ; 1877.	34
JASZAPATHI, . . .	Hungary, ...	1869.	1
JASZBERENY, . . .	,, ...	1868 N.–S. + 13 + 1 N.E.–S.W. + 9 + 1 E.–W. ; 1869 + 2 ; 1870 E.–W. ; 1872 + 2.	32
JASZMICHALYLEK, .	,, ...	(1868 + 1) E.–W. + 2 ; 1869.	5
JAUCHE, ...	Belgium, ...	1828 + 1.	2
JAZYGIA Comitat, . .	Hungary, ...	1868 + 7.	8
JEBEL TOOR, . . .	Arabia Petræa, . . .	1845.	1
JELABUGA KASAN, .	Russia, ...	1851.	1
JELASSULARY, . .	Baku Gov., Caucasus, . .	1879 + 1.	2
JELISABETHPOL, or Hamsha,	Georgia, . . .	1826.	1
JENBACH, . . .	Tyrol, ...	1872 ; 1878.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
JENIDJI, ...	Roumelia, Turkey, . .	1863 ; 1864.	2
JENDGEN, ...	Bavaria, ...	1847.	1
JERISÆ VILLAGE, .	Sweden, ...	1853 S.–N.	1
JERSEY ISLAND, . .	. . . . .	1750 ; 1791 + 1 ; 1804 ; 1843 + 1 ; 1868, extended to north coast of France—Morbihan (Côtes du Nord), 1872.	8
JERUSALEM, ...	Syria, ...	746 ; 1032 ; 1034 + 40, shocks for forty days ; 1105 ; 1113 ; *1834* ; 1856 ; 1863.	48
JESI, ...	Ancona, ...	1867 S.W.–N.E. ; 1870 + 1.	3
JEVISSERIK, . . .	Persia, ...	1857 + 1.	2
JEZSA, ...	Torontal Com., Hungary, .	1880.	1
JITHORE, ...	. . . . .	1843.	1
JINIS, ...	Armenia, ...	*1857* E.–W. + 18, extended to Erzeroum.	19
JOACHIMSTHAL, . .	Bohemia, ...	1552.	1
JOEGERTHAL, . .	Bas Rhin, ...	1846 E.–W.	1
JOGRY SUR VEVEY, .	Switzerland, ...	1880.	1
JOHANNESTHAL, . .	Silesia, Austria, ...	1871 + 4.	5
JOHANNGEORGENSTADT,	Saxony, Erzegebirge, . .	1701 ; 1770 ; *1771* + 3 ; 1856 S.W.–N.E. ; 1879.	8
JONCY, ...	Saône et Loire, ...	1874.	1
JÖN KOPPING, . .	Lake Wetter, Sweden, .	1759 + 3 ; 1851 + 2 S.W.–N.E.	7
JONZAC.	Charente Inférieure, . .	1874.	1
JOPPA, ...	Palestine, ...	1546.	1
JORIO, ...	Ischia Island, ...	1864.	1
JOSEPHTHAL, . .	Littschau Dis., Lr. Austria,	1854 + 9 ; 1856 + 2 + 1 S.W.–N.E., R. = 2 leagues ; (1857 + 8) S.W.–N.E. + 1 S.–N.	24
JOSSELIN, ...	Morbihan, France, . .	1772 N.E.–S.W.	1
JOUX, FORT DE, . .	Doubs, ...	1865 E.–W.	1
JOUX VALLEY, . .	Vaud Canton, ...	1881.	1
JUDEA, ...	. . . . .	1182 + 1.	2
JUDENBURG, . . .	Mur Valley, Styria, . .	1812 ; 1813 + 1 ; 1843 ; 1857 + 1 ; 1875 ; 1877 + 5 ; 1878 ; 1880 ; 1881 + 3.	19
JUGENHEIM, . . .	Darmstadt, ...	1869 ; 1873 + 1 ; 1874 + 1.	5
JULIAN ALPS, . .	. . . . .	1869 ; 1881.	2
JÜLICH = JULIERS, .	N.E. of Aix-la-Chapelle, .	1874.	1
JULIER PASS, . .	Grisons, ...	1871.	1
JURA Department, . .	. . . . .	1851 ; 1877 ; 1881.	3
JUTLAND, ...	Denmark, ...	*1841* + 1 ; 1867 ; 1882 (southern part of).	4

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
KAATWYK SUR MER, .	Holland, ...	1849.	1
KACSKO, ...	Szolnok-Doboka C., Hungary,	1881.	1
KADARKUT, . . .	14 miles N.W. of Szigeth, [Hungary,	1875.	1
KADEN, ...	Bohemia, ...	1811.	1
KAGUL District, . .	Bessarabia, 15 versts from [Bolgrad,	1857.	1
KAHLA, ...	Altenburg, S.W. Germany, .	1785.	1
KAISARIEH, . . .	Cappadocia, . . .	*1835* + 6, 30 miles radius ; 1836 + 1.	9
KAISERLAUTERN, . .	Bavaria, ...	1869 s.–n. + 3 ; 1878.	5
KAISERSEICH, . .	Brandenbourg, . . .	1869.	1
KALAMAKI, . . .	Corinth Isthmus, Greece, .	1850 ; 1855 ; 1858 + 1 ; 1859 + 2 ; 1860 + 1 ; 1861 + 6 ; 1862 ; 1866 + 3.	21
KALAMATA (*see* Calamatta), ...		——	
KALAMI, ...	Messenia Province, Greece, .	1846 ; 1860.	2
KALATSCHA-Partschinis,	Russian Armenia, . .	1871.	1
KALAVRYTA, . . .	Greece, ...	*1880*, the zone of greatest intensity extended from Leucosea across the Peloponessus to Dura near Tripolis, north coast of Africa—the river Strezowa dried up, the Phenœus sank deeper, and the Ladon ceased to flow during five hours.	1
KALENBERG = Calenberg,	Cobourg, ...	1855 + 1 s.–n.	2
KALKI ISLAND, near	Rhodes, ...	1843 ; 1862.	2
KALLARASH, . opposite	Silistria, Wallachia, . .	1864 + 1.	2
KALLEMBERG, . near	Waldemberg, Saxony, . .	1861 s.w.–n.e.	1
KALSCHING, . . .	Bohemia, ...	1880.	1
KALTENBRUNN, . .	Bavaria, ...	1878.	1
KALUNGA, . . .	Russia, ...	1802.	1
KALW, ...	Swabian Alps, . . .	(1830 + 2) w.–e.	3
KALYMNOS ISLAND, .	Sporades Islands, . .	1869.	1
KAMINIECK = Kaminietz,	W. Russia, . . .	1666 + 3.	4
KANDAL, ...	Rhine Valley, . . .	1869.	1
KANDEN, . . .	Bohemia, ...	1862 + 3.	4
KANDERGRUND, . near	Frutigen, Berne, . . .	1845.	1
KANDERN, . . .	Baden, S.W. Germany, .	1812 ; 1881.	2
KANDERSTEG, . .	Berne, ...	1855.	1
KANDL, ...	Tyrol, ...	1865 + 2.	3
KANTURK, . . .	County Cork, . . .	1868.	1
KAPAL, ...	Semipalatinsk Gov., Asiatic [Russia,	1856 n.–s.	1
KAPFENBERG, . .	Styria, ...	1864 n.w.–s.e.	1
KAPNICK, . . .	Transylvania, . . .	1783 + 1.	2
KAPOLNA, . . .	Szolnok-Doboka Com., [Hungary,	1881.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
KAPOSWAR, . . .	Somogyer Com., Hungary, .	1880 N.–S.	1
KAPPEL = Windish Kappel,	Carinthia, ...	1880.	1
KAPRINA-TEOPLITZ, .	Croatia, 13 miles N. by W. [of Agram,	1873 + 1.	2
KARABAREN, . . .	Grecian Archipelago, . .	1845.	1
KARABOURNOU, . .	Asia Minor, ...	1860.	1
KARAKORUM = Holin-Kolin,	Central Asia, . . .	1299, place destroyed.	1
KARAMARJANSK, . .	Caucasus, ...	1869.	1
KARCZAG, ...	Hungary, ...	1829 + 6, included a district of about 45 geographical miles from E. to W. by 10 from N. to S.	7
KARIPATZ = RASIPATZ,	Northern Russia, . .	1823 + 1 ; 1833.	3
KARLSDORF, . . .	Croatia, ...	1879 + 20.	21
KARLSFELD, . . .	Saxon Voigtland (*see* Carls- [feld,		
KARLSTADT, . . .	Wemerland, Sweden, . .	1765 + 3 ; 1822 ; 1855.	6
KARLSTADT, . . .	Croatia, ...	1852 + 1 ; 1863 + 1 ; 1870 S.E.–N.W. ; 1873.	6
KARPENESI, . . .	Elis, Greece, . . .	1861 + 1.	2
KARS, ...	Caucasus, ...	1868 + 2.	3
KARTAL DAGH, . .	Asia Minor, . . .	1871.	1
KARTEPOLI, . . .	Messenia Prov., Greece, .	1846.	1
KARTITSCH, . . .	Pusterthal, Tyrol, . .	1848 ; 1862 + 2.	4
KARTOUM, . . .	Upper Egypt, . . .	1854.	1
KARUGUSH Mountains, .	40 versts from Baku, and 20 versts from the sea—Caucasus. Lat. 40° 17′ 50″, Long. 67° 17′ 18″ E. from Island Ferro,	1854, eruption of black clay mud ; 1859.	2
KASCHAU, . . .	Hungary, ...	1834 ; 1858 S.E.–N.W.	2
KASSABA, . . .	Asia Minor, . . .	1860.	1
KASSTEIN, . . .	Pusterthal, Tyrol, . .	1862 + 2.	3
KASTRI, ...	Corinth Gulf, Greece, . .	1870.	1
KATHERINENFELD, .	Tiflis, Caucasus, . . .	1862 S.E.–N.W.	1
KATTOWITZ MINE, .	Silesia, Prussia, . . .	1875.	1
KATTSDORF, . . .	Upper Austria, . . .	1868 + 2 ; 1869 + 1.	5
KATZHÜTTE, . . .	Thuringerwald, . . .	1831.	1
KATZIKOVI, . . .	Messenia Province, Greece, .	1846.	1
KAUB, ...	20 miles S.E. of Coblentz, .	1875.	1
KAUDEN, ...	Bohemia, ...	1862 + 5.	6
KAVALA = CAVALLA, .	Roumili, Turkey, . .	1864 ; 1869 + 1 ; 1870 + 1 ; 1871 + 6 ; 1872 + 1.	14
KEBBAN-MADEN, . near	Diarbekir, Kurdistan, . ,	1874 S.W.–N.E. + 7, town destroyed.	8
KEHL, ...	. . . . .	1876 W.–E.	1
KELEGYHAZA, . .	. . . . .	1869 S.–N.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
KELLBERG, . . .	Lower Bavaria, . . .	1858.	1
KELLERBERG, . .	Carinthia, ...	1881 N.W.–S.E.	1
KELLINGHAUSEN, .	Denmark, ...	1755.	1
KELTON, ...	. . . . .	1844.	1
KELTSCH, . . .	Moravia, Austria, . .	1786, felt all along a line 35 geographical miles long, N.E.–S.W., in the direction from Brünn to Cracow.	1
KELVINSIDE, . near	Glasgow, ...	1880.	1
KEMI, ...	Lapland, ...	1758.	1
KEMPENICH, . . .	Adenau C., Rhenish Prussia,	1869.	1
KEMPTEN, . . .	Bavaria, ...	1842.	1
KENDAL, ...	. . . . .	1768 ; 1865 ; 1871.	3
KENDBERG, . . .	Styria, ...	1857 + 1 ; 1865.	3
KENI, ...	Bessarabia, ...	1834.	1
KENT, ...	. . . . .	1246 ; 1580 ; 1727.	3
KENTCHURCH, . .	. . . . .	1853.	1
KENZINGEN, . . .	Baden, S.W. Germany, .	1823.	1
KERCHINAGY, . .	14 miles from Gross Wardein [Behar Com., Hungary,	(1856 + 1) S.–N.	2
KEREPES, . . .	Hungary, ...	1763.	1
KERKOUK, . . .	Mesopotamia, S.E. of Mœssul,	1862 ; 1869 + 2.	4
KERKRADE, . . .	Limbourg, ...	1874 N.E.–S.W.	1
KERN = KIRN, . .	. . . . .	——	
KERTEL BAY, . .	Baltic, ...	1858.	1
KERZERZ, . . .	Fribourg, Switzerland, .	1882 + 1.	2
KES-KOMARUM = Kis Komarum, Hungary, . . .		1869 + 3.	4
KESMARK, . . .	Hungary, ...	1876.	1
KESTERN, . . .	Austrian Poland, . .	1840 + 2.	3
KESTERT, . . .	Nassau, S.W. Germany, .	1869.	1
KESWICK, . . .	. . . . .	1787.	1
KETTENHEIM, . .	Darmstadt, ...	1869 + 2.	3
KEW, ...	. . . . .	1878.	1
KEWRAG, . . .	Caucasus, ...	1841 + 4.	5
KHABOOSHAN, . .	Khorassan, Persia, . .	*1871 + 1*, the town destroyed.	2
KHALKI ISLAND, . .	W. of Rhodes, . . .	1862 + 6.	7
KHODJEND, . . .	Syr Darya, Asiatic Russia, .	1866 ; 1867 ; (1868 + 2) N.–S. + 2 S.–N. + 3 ; 1869 N.E.–S.W. + 1.	12
KHOI, ...	Aderbaidjân Prov., Persia, .	1842, town partly destroyed ; 1867 + 1 ; 1881 + 42.	46
KHORASSAN, . . .	. . . . .	817 ; 856.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
KIAKTA, ...	91 versts from Selenginsk [Kurdistan,	1771 + 1; 1856 + 2, over an area of 500 miles sq.; 1857 + 4.	10
KIEFERSFELDEN, . .	Bavaria, ...	1879.	1
KIEFF, ...	Russia, ...	1730; 1790; 1793; 1802; *1821* E.–W. + 2 + 3; 1829.	11
KILKENNY, . . .	. . . . .	1690.	1
KILLIN, ...	. . . . .	1831.	1
KILMARTINE, . .	. . . . .	1880.	1
KILMICHAEL, . .	. . . . .	1880.	1
KILRUDDERY, . .	. . . . .	1852.	1
KILTERSBACH, . .	Rhine Valley, . . .	1869 + 2.	3
KIMPOLUNG, . . .	Transylvania, . . .	1855 S.E.–N.W.	1
KINDBERG, . . .	Styria, ...	1830 + 1; 1857; 1876.	4
KINGENFELD, . .	S.E. of Nassenfuss, Carniola,	1871 + 7.	8
KINGSBURY, . . .	Parret Valley, . . .	1868.	1
KINGSDOWN, . . .	. . . . .	1839; 1852.	2
KINGSTOWN, . . .	Dublin, ...	1852.	1
KINLOCKMORDART, .	Argyleshire, . . .	1841.	1
KINSALE, . . .	. . . . .	1777.	1
KINSERVIG, . . .	Norway, ...	1855 N.–S.	1
KINTAIL, . . .	. . . . .	1820; 1841.	2
KIONKABLE, . . .	W. Gothland, Sweden, .	1809.	1
KIPARISSA, . . .	Morea, ...	*1875*, destructive.	1
KIPPIN, ...	. . . . .	1820.	1
KIRCHAIN, . . .	Cassel, S.W. Germany, .	1869 + 1 N.–S. + 1.	3
KIRCHBACH, . . .	Styria, ...	(1869 + 1) S.W.–N.E.; 1880 + 2.	5
KIRCHBERG, . . .	Würtemberg, . . .	1846; 1869.	2
KIRCHBERG, . . .	Saxony, ...	1859.	1
KIRCHBERG, . . .	Lower Austria, . . .	1875 + 1; 1881.	3
KIRCHBERG, . . .	Coblentz C., Rhenish Prussia,	1869 + 2.	3
KIRCHDORF, . . .	Berne Canton, Switzerland,	1852; 1873 S.–N.	2
KIRCHDORF, . . .	Upper Austria, . . .	1856 + 1.	2
KIRCHEIM, . . .	. . . . .	1855; 1869.	2
KIRCHEN, . . .	Altenkirchen C., Rh. Prussia,	1869 + 3.	4
KIRCHOFEN, . . .	Baden, ...	1870 S.W.–N.E. + 1.	2
KIRCHSLAG, . . .	Upper Austria, . . .	1867; 1868.	2
KIRENSK, . . .	Irkutsch Gov., Siberia, .	1856 + 2.	3
KIRGHIS STEPPES, .	Asiatic Russia, . . .	1846 + 3.	4
KIRKHAM, . . .	. . . . .	1871.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
KIRLEBABA, . . .	Bukovina, ...	1877 + 1 S.E.–N.W. + 1 S.–N.	3
KIRMATSHI, . . .	S. of Lake Appolonia, Asia [Minor,	1850 + 1, crevasse formed, from which was thrown up water mixed with sand.	1
KIRN, ...	Rhenish Prussia, . .	1869 + 1.	2
KISCHENEW, . . .	Bessarabia, ...	1827 + 1; 1829; 1831 + 1; 1834 + 1; *1835* N.–S. 1843 N.–S.; 1844; 1848; 1856; 1857; 1862; 1864 + 1; 1865 S.E.–W. + 2; 1868 + 1; 1870; 1880 + 3.	25
KISCHTIMSKI MINES, .	Ural, ...	1836.	1
KISGAR, ON THE TEREK,	Caucasus, ...	1785; 1830.	2
KISKAMAROON, . .	Hungary, ...	1869 + 1.	2
KISLOVODSK, . .	Russia, ...	1866, felt also at Essentoisi, Jeleznovodsk, and Pratigorsk.	1
KISTON IN LINSAY, .	. . . . .	1818.	1
KITOW, ...	Tarnapol Gov., Galicia, .	1851; 1852.	2
KITZINGEN, . . .	Bavaria, ...	1876.	1
KIUTAHYAH, . . .	Asia Minor, . . .	1850.	1
KIVARELI, . . .	Caucasus, ...	1856.	1
KIVISCHET = KIVICHET,	,, ...	1857 + 2.	3
KLADNO, ...	Bohemia, ...	1872; 1881.	2
KLANA, . . . near	Castua, Istria, . . .	*1870* + 7 + 1 E.N.E.–W.S.W. + 5; 1874 S.W.–N.E.	15
KLAUSENBURG, . .	Transylvania, . . .	1880 + 3.	4
KLAUSEN LEOPOLDORF,	Austria, ...	1875.	1
KLEIN ENGSTINGEN, .	Würtemberg, . . .	1828.	1
KLEIN KOPPISH, . .	Transylvania, . . .	1880.	1
KLEIN REIFLING, .	Styria, ...	1875 + 1.	2
KLEIN RESTENBACH, .	Odenwald, Hesse, . .	1867.	1
KLEINUMSTADT, . .	Darmstadt, ...	(1787 + 1) E.–W.	2
KLEUR, ...	Comorn C., Hungary, . .	1866.	1
KLITORIA, . . .	Greece, ...	1880.	1
KLITTEN, . . .	Veile, Denmark, . . .	1882.	1
KLOBENSTEIN (AUF DEM	RITTEN), Tyrol, . . .	1873.	1
KLOSTER, . . .	Lower Austria, . . .	(1876 + 1) S.E.–N.W.	2
KLOSTERS, . . .	Grisons, ...	1863.	1
KLUC, ...	Bosnia, ...	1880 S.W.–N.E.	1
KLUDOW, . . .	Russian Turkestan, . .	(1868 + 1) N.–S.	2
KNALKRI ISLAND, .	Grecian Archipelago, . .	1863.	1
KNAPPENBERG, . .	Styria, ...	1878 + 1.	2
KNIEBIS, ...	Würtemberg, . . .	1874 + 3; 1875.	5
KNIN, ...	Dalmatia, ...	1876 N.–S.	1
KNITTENFELD, . .	Styria, ...	1864 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
KNOLE, ...	. . . . .	1867.	1
KNOTSFORD, . . .	. . . . .	1753.	1
KOBY, ...	Caucasus, ...	1868 + 3.	4
KODJA-BERRÉ, . .	Algeria, ...	*1843*.	1
KŒNIG, ...	Darmstadt, ...	1869.	1
KŒNIGGRÄTZ, . .	Bohemia, ...	1786.	1
KŒNIGSBERG, . .	W. of Frankfort, . .	1619 ; 1780.	2
KŒNIGSFELD, . .	Ahrweiler C., Rhenish Prussia,	(1869 + 1) W.–E.	2
KŒNIGSFELDEN, . .	Aargau, Switzerland, . .	1851 E.–W.	1
KŒNIGSHUTTE, . .	Upper Silesia, . . .	1875 ; *1877 + 2*, limits of shock—Trier, Elupen, Düren, Brüssil, Mechlin, Geldern, Wesil, Dorsten-on-Lippe, Köln, Remschied—strongest at Herzongenrath, Geilenkirchen, and Heinsberg.	4
KŒNIGSTEIN, . .	Nassau, ...	1878.	1
KŒNIGSWALDE, . near	Annaberg, Saxon Voigtland,	1862.	1
KŒNIGSWINTER, . .	Westphalia, Prussia, . .	1856 ; 1869 + 1 + 1 S.W.–N.E.	4
KŒNITZ, . . . near	Berne, ...	1821.	1
KŒVORDEN, . . .	Dreuthe Province, . .	1854 S.E.–N.E. + 3, ramparts broken through.	4
KÖHL = KEHL, . .	Baden, ...	1822 ; 1825 + 3 ; 1871 + 2 ; 1876 W.–E.	9
KOHLSCHIED, . near	Aix-la-Chapelle, . . .	1869 ; 1873 + 1 ; 1874 N.E.–S.W. + 2.	6
KOHLSTETTEN, . .	Swabia, ...	1828.	1
KOKINE-SAI, . . .	10 versts S. of Khojend, .	(1868 + 1) N.–S.	2
KOKINYOS, . . .	Marmoros C., Hungary, .	1880 N.E.–S.W.	1
KOLA, ...	Lapland, ...	1758 ; 1772.	2
KOLDING, . . .	Veile, Denmark, . . .	1882.	1
KOLEAH, ...	Algeria, ...	1847 ; 1867 + 3.	5
KOLY, ...	Bihar Com., Hungary, .	1868.	1
KOMOTAU, . . .	Saxon Voigtland, . .	1862 + 1 ; 1872.	3
KONGSBERG, . . .	Norway, ...	1774.	1
KONGSWINGER, . .	Christiana Province, Norway,	1844 + 1.	2
KONIEH, ...	Karaman, Asia Minor, . .	1863 + 3 ; 1866 + 1.	6
KONITZA, . . .	Epirus, ...	1860 + 6.	7
KOPREINITZ, . . .	Croatia, ...	1876 N.–S. ; 1878 S.E.–S.W. ; 1880.	3
KORBITZ, . . near	Kaaden, Bohemia, . .	1860.	1
KORDIK, ...	Neusohl, Hungary, . .	1862.	1
KORK, ...	Baden, ...	1825 + 2.	3
KOSTAJNITZA, . .	Croatia, ...	1861 ; 1876 S.E.–N.W.	2
KOSTANJEVAC, . .	Illyria, ...	1870.	1
KOSTHEIM, . . .	Mainthal, ...	1869 W.–E. + 2 S.W.–N.E. + 2 ; 1870.	6

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
KOTSCHACH, . . .	Gmünd, Illyria, . . .	1869.	1
KÖTTMANNSDORF, .	Carinthia, ...	1880 + 1.	2
KOUBA, ...	Georgia, ...	*1828 + 2.*	3
KOUBAH, ...	Algeria, ...	1847.	1
KOUBAN Riv. (Mouth of),	Black Sea, ...	1834.	1
KOUBATZI, . . .	Eubœa, Negropont Island, .	1852 + 1; 1857 + 3; 1858 + 4; 1859 + 1; 1866 + 6; 1881.	21
KOUBEÏ, ...	Bessarabia, Lower Danube, .	1864; 1868 + 1.	3
KOUCHENGINDJE, . .	Caucasus, ...	1861.	1
KOUROU TSCHESME, near	Constantinople, . . .	1858 S.–N.	1
KOURT KOUTZI, . .	Messenia Province, Greece, .	1846.	1
KOUVRE, ...	Croatia, ...	1834 N.E.–S.W.	1
KOVASZNA, . . .	Hungary, ...	1861.	1
KRAINBURG, . . .	Carniola, ...	1879 + 1; 1882.	3
KRAJOWA = CRAJOWA,	Wallachia, ...	1802.	1
KRALJEVICA, . . .	Croatia, ...	(1874 + 1) N.W.–S.E.	2
KRALUP, ...	Bohemia, ...	1872.	1
KRANAU, ...	Bohemian Frontier, . .	1818.	1
KRANICHBERG, . near	Glognitz, Lower Austria, .	1870 + 1; 1875 + 3.	6
KRAPINA TOEPLITZ, .	Agram, ...	1873 + 1; 1880.	3
KRASNOJARSK, . .	Volga, ...	1858.	1
KRATIK, ...	Neusohl, Hungary, . .	1862.	1
KRAUBEL, . . .	Styria, ...	1881 W.–E.	1
KREMBERG, . . near	Leybach, Carniola, . .	1868 + 3.	4
KREMESNIK, . . .	Tabor District, Bohemia, .	1877.	1
KREMNITZ, . . .	Hungary, ...	(1861 + 1) N.W.–S.E.; 1862 + 2.	5
KREMS, ...	Weisskirchen, Austria, .	(1858 + 3) S.E.–N.W.; 1862 N.–S. + 1 N.W.–S.E.; 1865; 1880.	8
KREMSMÜNSTER, . .	Traun Cir., Austria, . .	1826 + 2; 1858.	4
KRESHKEMET, . .	Hungary, ...	1863; 1865 + 2; 1868.	5
KREUTZ, ...	Croatia, ...	1851 + 1.	2
KREUTZ, Comitat, . .	Hungary, ...	1880.	1
KREUTZLINGEN, . .	Thurgau, Switzerland, .	1881.	1
KREUTZNACH, . .	Nahethal, Rhenish Prussia, .	1869 + 3.	4
KRONAK, ...	Bavaria, ...	1869 + 1 S.–N.	2
KRONBERG Mountains, .	Appenzell, Switzerland, .	1619.	1
KRONSTADT, . . .	Transylvania, ...	1802; 1829; 1838 + 1; 1854 + 1; (1855 + 3) S.E.–N.W.; 1861 + 3; 1862 + 3; 1863; 1868 + 4; 1869; 1872; 1876.	27

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
KROSOWICKA, . .	Galicia, Austria, . . .	1785.	1
KROTENDORF, . .	Upper Saxony, . . .	1821.	1
KRUMMBACH, . .	Baden, ...	1871.	1
KRUSCHEWITZA, . .	Servia, ...	1881.	1
KUBANSK, . . .	Black Sea Coast, W. of [Caucasus,	1870 N.E.–S.W.	1
KUBEA = KABA, . .	Southern Russia, . .	1868 + 2 + 2 S.W.–N.E.	5
KUBLIS, ...	Grisons, ...	1880 + 2.	3
KUFSTEIN, . . .	Tyrol, ...	1862; 1865; 1875 + 2; 1879.	6
KUMI, ...	Eubea, ...	1860 + 1; 1866 + 1; 1867 + 1.	6
KUNDL, ...	Tyrol, ...	1865 + 3; 1870 + 4; 1871 + 1.	11
KUPFINBERG, . .	Styria, ...	1864 N.W.–S.E. + 1 N.W.–S.E.	2
KURATIN-WIDAIN, .	Tyrol, ...	1878.	1
KURDISTAN, . . .	. . . . .	1871 + 10.	11
KUSSARY, . . .	11 versts N.W. of Kuba, [Caucasus,	1868 S.E.–N.W. + 1.	2
KUSTAIAH = KUSTAYA,	Anatolia, ...	1860.	1
KUSTENDJI, . . .	Lower Danube, . . .	1868 + 1 S.–N. + 4 W.–E; 1869; 1870.	8
KUVIA, ...	Hungary, ...	1874.	1
KWARIL, ...	Teluf Circle, Tiflis Gov., .	1851 + 1.	2
KWIRLISK, . . .	Schoropan, ...	1868 + 12.	13
KWISCHET, . . .	Lat. 42° 27′. Long. 42° 14′. On the main road through the Caucasus, from Tiflis to Russia by Wladekowakay,	1857 + 3; 1868 + 6.	11
KYBORG, ...	Zurich Canton, . . .	1672.	1
KYETINSK, . . .	Southern Ural, . . .	1836; 1837.	2
KYLLBURG, . . .	Rhenish Prussia, . . .	1878.	1
LAACH, ...	Rhenish Prussia, . . .	1869 + 1.	2
LAACHER SEE, . .	. . . . .	1869 + 1; 1871 + 1.	4
LAAS, ...	Carniola, ...	1870 + 4.	5
LA BARTHE DE NESTE,	Hautes Pyrénées, . .	1776; 1864 + 4.	6
LA BASTIA, . . .	Perugia, Italy, . . .	1832.	1
LA BASTIDE, . . .	Lot, ...	1852.	1
LA CALLE, . . .	Algeria, ...	1856; 1858, extended to Nice, + 1.	3
LA CANNARA, . .	Perugia, ...	1832.	1
LA CAVA, . . .	Principato, Italy, . .	*1684.*	1
LACEDEMON, . . .	. . . . .	B. C. 550 to 530.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LA CHAPELLE SUR ENDRE,	(Loire Inférieure), Nantes [Arrondissement,	1877.	1
LA CHARTRE, . . .	Indre, ...	1813 ; 1857 N.E.–S.W. ; 1866 E.–W.	3
LA CHIFF VILLAGE, .	Algeria, ...	1867 + 7 ; 1869.	9
LA CONCEPTION, . near	Donfront, Orne, . . .	1778.	1
LACONIA, . . .	Greece, ...	1867.	1
LA DARDO, . . .	Southern Tyrol, . . .	1877 + (7 + 1) N.–S.	9
LA FAVORITA, . .	Sicily, ...	1868.	1
LA FLOTTE, . . .	Charente Inférieure, . .	1804 + 1.	2
LA GARDE, . . .	Dauphiny, ...	1773.	1
LAGHOUAT, . . .	Algeria, ...	1867.	1
LAGNES, . . .	Vaucluse, ...	1863 + 2.	3
LAGO DI VICO (Ciminius Lacus).	Etruria, . . .	B. C. 1450.	1
LAGO MAGGIORE, . .	. . . . .	1867, extended to (Sesta calende), Milano ; 1881.	1
LAGO NEGRO, . .	Basilicata, ...	1825 ; 1831 ; 1851 ; 1852 + 1 ; 1855 + 1 ; 1857 + 3 ; 1858 + 10 ; 1860.	23
LAGOSTA ISLAND, .	Dalmatia, ...	1837 E.–W.	1
LA HAYE (THE HAGUE),	Netherlands, . . .	1843 + 1.	2
LAHN VALLEY, . .	. . . . .	1869.	1
LAHR = LOHR, . .	Baden, ...	1807.	1
LAIBACH = LJUBLJANA,	Carniola, ...	985 ; 1077 ; 1118 ; 1131 ; 1236 ; 1311 ; 1357 ; 1431 ; 1449 ; 1507 ; 1511 ; 1531 ; 1575 ; 1621 ; 1622 ; 1633 ; 1641 ; 1643 ; 1654 ; 1669 ; 1684 ; 1686 ; 1690 ; 1691 ; 1776 ; 1801 ; 1802 ; 1813 + 2 ; 1822 ; *1832* + 1 ; 1835 ; 1836 E.–W. ; 1845 + *1* S.W.–N.E. ; 1850 + 1 ; (1852 + 1) S.W.–S.E. + 1 ; 1865 + 7 + 1 N.–S. + 2 S.E.–N.W. ; (1857 + 4) N.–S. + 1 S.E.–N.W. ; 1858 + 2 + 2 E.–W. ; 1859, felt also at Trieste, + 1 ; 1861 + 1 ; 1862 ; 1863 ; 1864 ; 1866 N.–S. ; 1867 W.–E. + 3 ; 1868 + 9 ; 1869 3 + 1 E. W. + 2 N.W.–S.E. ; 1870 + 4 + 1 N.W.–S.E. + 1 W.–E. ; 1871 + 2 ; 1872 ; 1873 [illegible] N. ; 1874 ; 1877 ; 1879, extended over part of Lower Styria, Carinthia, and Kustenland, + 3 ; 1880 ; (1881 + 2) E.–W. ; (1882 + 3 + 1) W.–E.	120
LAMBESU, . . .	Algeria, ...	1858.	1
LAMBRECHT (GRAVENHAUSEN),	Bavaria, . . .	1869 E.–W.	1
LAMBROOK, E., . .	. . . . .	1868.	1
LAMENE, ...	Romagna, ...	1881.	1
LAMIA, ...	Photis, Greece, . . .	1858 + 1 ; 1864 ; 1867 ; 1869 + 3 ; 1882.	9
LAMLASH, . . .	. . . . .	1880.	1
LÄMMERSPIEL, . .	Mainthale, ...	1869 + 2.	3
LA MOTHE, ST. HERAYE,	Deux Sèvres, . . .	1866.	1
LA MOTHE, . . .	Isère, ...	1849 + 1.	2
LA MOTHE, . . .	Basses Alpes, . . .	1866.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LAMPERTHEIM, . .	Darmstadt, ...	1869 + 1 ; 1872 + 1.	4
LAMPERTSLOCH, . .	Alsace, ...	1825.	1
LANCASHIRE, . .	. . . . .	1817 ; 1839 ; 1843 ; 1869, eastern part of, + 1 ; 1871.	6
LANCASTER, . . .	. . . . .	1750 ; 1777 ; 1786 ; 1835 ; 1842 ; 1863 ; 1868.	7
LANCLANO, . . .	Abruzzi, ...	1842 ; 1871.	2
LANCRANO, . . .	Abruzzi, ...	1841 ; 1863 ; 1881 + *1*, extended from Vasto, on the Adriatic to Naples.	4
LANDECK, . . .	Innthal, Tyrol, . . .	(1880 + 1) E.–W. ; 1881 S.E.–N.W., connected with the Carinthian earthquake.	3
LANDENHAUSEN, . .	Darmstadt, ...	1869.	1
LANDERNAU, . . .	Finistère, ...	1776.	1
LANDÉRON, . . .	Neuchatel Canton, . .	1856.	1
LANDERSHUT, . .	Silesia, ...	1799.	1
LANDERSHUT, . .	Bavaria, ...	1750 + 2 ; 1787 ; 1819 ; 1822 + 4.	10
LANDQUART R., . .	Grisons, ...	1881.	1
LANDSTRASS, . .	Carniola, ...	1867 + 1 ; 1870 ; 1881 + 3.	7
LANDSTUHL, . . .	Bavaria, ...	1869 ; 1878.	2
LANGÉ, ...	Indre, ...	(1841 + 3) S.–N.	4
LANGEN, ...	Darmstadt, ...	1869 + 1.	2
LANGEN, ...	Tyrol, ...	1881 S.W.–N.E.	1
LANGENBROMBACH, .	Darmstadt, ...	1869 + 3 ; 1873.	5
LANGENBRUCK, . .	Bâle, ...	1870.	1
LANGENGOENS, . .	Darmstadt, ...	1869 + 1.	2
LANGENKANDEL, . .	Bavaria, ...	1880.	1
LANGENLONSHEIM, .	Creuznach C., Rh. Prussia, .	1869 + 6.	7
LANGENSCHWALBACH,	Nassau, ...	1869 + 1.	2
LANGENWANG, . .	Mürzthal, Styria, . .	1876 + 1.	2
LANGESUND, . . .	Bradsberg, Norway, . .	1866.	1
LANG-GÖNS, . . .	Upper Hesse, . . .	1869 W.–E.	1
LANGHIRANA, . .	Parma, ...	1832.	1
LANGÖRE, . . .	Iceland, ...	1784 + 2.	3
LANGPORT, . . .	Parret Valley, . . .	1868.	1
LANGRES, . . .	Haute Marne, . . .	1783 ; 1810 ; 1855 ; 1862.	4
LANGRIDGE, . . .	. . . . .	1871.	1
LÄNGSEE, . . .	Carinthia, ...	1880 S.W.–N.E.	1
LANMERZAN, . . .	Basses Pyrénées, . . .	(1863 + 2) W.–E.	3
LANNESDORF, . .	Bonn C., Rhenish Prussia, .	1869.	1
LANO, ...	Albania, ...	1858.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LANSKORAN, . . .	Caspian Sea Shore, . .	1860.	1
LANZO VALLEY, . .	Piedmont, ...	1767.	1
LAODICEA, . . .	Syria, ...	B. C. 22; A. D. 50; 58; 127; 494; 859, part of Askræos mountain fell into the sea; *1790* + 2.	9
LAON, ...	Aisne, ...	1874 + 3.	4
LAPLANCHE, . . .	Loire Inférieure, . .	1862 W.–E.	1
LAPLAND, . . .	. . . . .	1750; 1811 + 2.	4
LAPLAND (Russian), .	. . . . .	1758 + 1, lasted three hours, extended along the White Sea, at Kola and environs.	2
LA PUGLIA, . . .	. . . . .	1087; 1088; 1361 + 3, at Oscoli 4000 people perished; 1454; 1626, the places most injured lay in a line running N.–S. from the eastern side of the Appenines at Bovino to the Adriatic Sea at the mouth of the river Fortore, 17,000 people killed, clefts opened in the ground, lakes dried up, mountains cleft, jets of water and mud thrown up out of the wells, + 4; 1628, 7000 people perished; *1646* + 4; 1689 S.–N.; 1730 + 1; 1731; 1732; 1739; 1777; 1787 + 3; 1805; 1851; 1875.	30
LARI, ...	Pisa, ...	1846; 1848.	2
LARIGNAN, . . .	Switzerland, . . .	1852.	1
LA ROCHE CHEVRON, .	Savoie, ...	1852.	1
LA ROCHELLE, . .	Charente Inférieure, . .	1772 S.–N.; 1776 + 6; 1780; 1781; 1783; 1784 + 1; 1786; 1802; 1810; 1829 + 1, R. = 4 leagues; 1836; 1838; 1845; 1857.	22
LA ROCHETTE, . .	Maurienne, ...	1847, R. = 6 miles, + 2.	3
LA ROQUE, . . .	Pyrénées Orientales, . .	1797.	1
LARS, ...	Caucasus, ...	1851.	1
LASSBŒ-SAGEWERCKIN,	Helsingland, Sweden, . .	1779 + 1.	2
LARUNS CANTON, . .	Basses Pyrénées, . . .	(1844 + 1) E.–W., always parallel to the chain of the Pyrénées; 1868.	3
LASAREWSK, . . .	Caucasus, ...	1870.	1
LA SAUVE, . . .	Gironde, ...	1852.	1
LASINJA, ...	Croatia, ...	1870.	1
LASTRA, . . . near	Florence, ...	*1742*.	1
LATCHA VILLAGE, .	S. of Schemakha, . .	**1669**, swallowed up.	1
LATERA, ...	Bolsena Lake, Viterbo, .	1881 + 6; 1882 + 9.	17
LA TESTE, . . .	Gironde, ...	1854 + 1.	2
LA TOUR (COMMUNE), .	Savoie, ...	1808 + 72; 1810; 1818 + 9.	84
LA TRINITÉ-PORHOET,	Morbihan, ...	1860.	1
LATYSZEW, . . .	Poland, ...	1767.	1
LAUBACH, . . .	Rhenish Prussia, . . .	1869 N.–S. + 2; 1873.	4
LAUCHARTHAL, . .	Prussia, ...	1862.	1
LAUENEN VALLEY, .	Berne Canton, . . .	1853.	1
LAUFENBURG, . .	Aargau, ...	1870 + 2; 1878 + 1.	5

PLACES.	LOCALITIES	YEARS.	Total Number of Shocks recorded.
LAUNCESTOWN, . .	. . . . .	1873.	1
LAUNSBACH, . . .	Lahnthale, ...	1869 + 1.	2
LAUPEN (Chateau de, .	Berne Canton, . . .	1838.	1
LAUPHEIM, . . .	Würtemberg, . . .	1861.	1
LAURA, . . . near	Nola, Terra di Lavoro, .	1858 + 1.	2
LAUREANA, . . .	Calabria, ...	1869.	1
LAURENBURG, . .	Lahnthale, ...	1869.	1
LAURENZANA, . .	Basilicata, ...	1857.	1
LAURESHEIM, . .	Mayence, ...	A. D. 838.	1
LAURWIG, . . .	Norway, ...	1803 N.–S.; 1834.	2
LAUSANNE, . . .	. . . . .	1356; 1456; 1572; 1621; 1650; 1692; 1729; 1817 + 3; 1822; 1845; 1846 + 4; 1847 S.W.–N.E.; 1851 + 1; 1854 S.–N.; 1855 S.–N. + 1 N.N.W. + 3; 1856 S.–N. + 1; 1869 + 2; 1876; 1877 + 1; 1878; 1879 + 2; 1880; 1881 + 2 + 1 S.E.–N.E. + 3 S.W.–N.E. + 7.	54
LAUSANNE CANTON, .	. . . . .	1817.	1
LAUTERBACH, . .	Darmstadt, ...	1869.	1
LAUTERBACHTHAL, .	,, ...	1869.	1
LAUTERBRUNN Valley,	Berne Canton, . . .	1827; 1830; 1864; 1880; 1882.	5
LAUTERN, . . .	E. Prussia, ...	1873 + 2.	3
LAUVETERRE, . .	Basses Pyrénées . . .	1802.	1
LAVAL, ...	Mayenne, ...	1799; 1822; 1852; 1853 + 1.	5
LA VALLETTA, . .	Malta, ...	1868.	1
LAVANTHAL, . . .	Carinthia, ...	1879 + 1.	2
LA VAVRE, . . .	Rhône, ...	1841.	1
LAVAUX, ...	Berne Canton, Switzerland, .	1880, extended distance of 75 km. to Frutigen.	1
LAVELLO, . . .	Basilicata, ...	1851; 1854.	2
LA VENDÉE, . . .	. . . . .	1799.	1
LAVIANO, . . .	Principato C., . . .	1857 E.–W.	1
LAVIN, ...	Lower Engadine, . .	1853; 1860 + 2; 1882.	5
LAVINO, ...	Molise Province, . . .	1854.	1
LAVORGO, . . .	Ossola, Italy, . . .	1880 S.–N.	1
LAVOUR, ...	Tarn, ...	1867.	1
LAXADALE, . . .	. . . . .	1880.	1
LEAD HILLS, . . .	Scotland, ...	1823; 1821; 1826.	2
LEAMINGTON, .	. . . . .	1868.	1
LEBADIA, . . .	Beotia, Greece, . . .	1859; 1861.	2
LE BACH, . . .	Saarlouis C., Rhenish Prussia.	1869.	1
LE BLANC SUR INDRE,	Indre, ...	1851 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LECCE,	Terra di Otranto,	1744; (1844 + 1) S.E.–N.W.; 1846; 1851 + 1; 1858.	7
LECCO,	Lake Como,	1864 + 1.	2
LECUMBERRY,	Basses Pyrénées,	1858 + 1.	2
LEDENICE,	S. of Fiume,	1870.	1
LEEDS,	. . . . .	1780; 1795; 1871 + 1.	4
LEGESINO,	Uman C., Southern Russia,	1880.	1
LEGHORN,	. . . . .	1642; 1646 + 2, also at Constantinople; 1712; 1720 + 1; 1726; 1732 + 5, extended to Genoa; 1740; 1742 + 9 + 3 W.–E. + 1 S.E.–N.W.; 1752; 1759; *1771 + 17* + 2; 1777; 1778 + 1; (1798 + 1) N.–S.; 1799; 1800 + 1; 1804 + 1; 1805; 1808 + 3; 1811; 1814 + 1; 1818; 1825 + 2; 1827; 1841 + 2; 1843 + 2; 1846 S.W.–N.E. + 10; 1847 + 1; 1848 + 1; (1849 + 1) E.–W.; 1850 + 5; 1851 + 1; 1852 + 4; 1853 + 2; 1858; 1859; 1871 + 3 + 1 E.–W.; 1872 + 2;	124
LEGNAU,	Solothon C.,	1846.	1
LEGRAD,	Croatia,	1876.	1
LEICESTER,	. . . . .	1792; 1865 + 1.	3
LEICESTERSHIRE,	. . . . .	1750; 1776.	2
LEICHLINGEN,	Solingen C., Rhenish Prussia,	1869 S.–N.	1
LEIMEN,	Baden,	(1844 + 2) W.–E.	3
LEIMENTHAL,	. . . . .	1836.	1
LEIPZIG,	. . . . .	1711; 1718; 1720; 1763 + 1; 1833; 1842 + 1; 1843 + 4; 1848 N.E.–S.W.; (1857 + 1) W.S.W.–E.N.E.; 1862; 1866; 1872; 1875 + 10.	30
LEIRA,	Portugal,	1841 + 5.	6
LEKHÆNA,	Elis, Greece,	1861.	1
LEKSAND,	Storakopperberg Province [Sweden,	1856 N.E.–S.W.	1
LEMBERG,	Galicia, Austria,	1802; 1821 + 1; 1875.	4
LEMIA,	Greece,	1858 + 1.	2
LEMNOS ISLAND,	Grecian Archipelago,	1856; 1859; 1867.	3
LENDORF-VOLKERMARK,	Carinthia,	1882.	1
LENGNAU,	Aargau,	1870 + 1.	2
LENK,	Berne,	1816 + 1.	2
LENKORAN,	Schemakha, Caucasus,	1846 + 3; 1852 + 3; 1854; 1855; 1857 + 1; 1858; (1860 + 1) S.W.–N.E.; 1861 + 2; 1862 + 1; 1863 S.–N., extended to Ardebil in Persia, + 2; (1863 + 1) N.–S. + 3 S.–N.	28
LEOBEN,	Styria,	1794; 1830; 1856; 1858; 1863 + 1; 1864 + 1 N.W.–S.E. + 2; 1867 + 1; 1868 + 1; 1878 E.–W.; 1880.	16
LEON,	Spain,	1853.	1
LEONBERG,	Würtemberg,	1875 + 1; (1876 + 2) S.W.–N.E.	5
LEONTARI,	Peloponnesus,	1860.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LEOPOLDHAMMER,	Bohemia,	1824.	1
LEOPOLDHULL,	Saxony,	1880.	1
LEOPOLDSDORF,	Vienna District,	1875.	1
LEOPOLDSHAFEN,	Baden,	1880.	1
LEOPOLDSKIRCHEN,	Carniola,	1876 ; 1880 W.–E.	2
LEOVO,	Wallachia,	1831 + 1.	2
LEPANTO GULF,		1756 + 1 ; 1858.	3
LEPINI, Mountain and Volcano, Velletri,		1837 + 6.	7
LE QUESNAY,	Nord,	1828 + 1.	2
LERIDA,	Cataluña,	1855.	1
LERWICK,	Shetland Island,	1871.	1
LES GRANGES,	Rhône banks,	1873.	1
LESINA,	Capitanata,	1852 ; 1854 ; 1868 + 1.	4
LESINA ISLAND,	Dalmatia,	1859 + 10 + 1 W.–N.W. ; 1860 ; 1870 + 5 ; (1874 + 1) S.–N. + 2 + 1 S.W.–N.E.	24
LESKOVATZ,	Rumili,	1860 + 6.	7
LESNOJE,	12 versts from Black Sea [Caucasus,	1870 S.–N. + 7.	8
LES SABLES Arrondisement, (La Forez),		1877.	1
LESTELLE,	Basses Pyrénées,	1850.	1
LETTERKENNY,	Ireland,	1880.	1
LEUCOSIA,	Greece,	1880.	1
LEUK,	Valais,	1858 ; 1880 + 5 : 1881 + 2.	10
LEUTESDORF,	Neuwied C., Rhenish Prussia,	1869 W.–E.	1
LEUTMERITZ CIRCLE,	Bohemia,	1784.	1
LEUVEN = LOUVAIN,	Brabant, Belgium,	*See* Louvain.	
LEVINA ISLAND,	Dalmatia,	1859 + 4.	5
LEVISSY,	Rhodes Island,	1851.	1
LEWIS ISLAND,	Scotland,	1880.	1
LEYDEN,	Netherlands,	1755 ; 1760 + 2.	4
LIBOURNE,	Gironde,	1852.	1
LIBRILLA,	Murcia, Spain,	(1855 + 4) E.–W. ; (1856 + 4) E.–W. ; 1864.	11
LICHTENWALD,	Styria,	1877 + 1.	2
LIDORIKI,	Doris, Greece,	1860 + 1.	2
LIEBENZELL,	Würtemberg,	1857 N.–S.	1
LIEBWERDA,	Bohemia,	1799.	1
LIEDBERG,	Gladbach C., Rhenish Prussia,	1862 ; 1869.	2
LIÈGE,		1117 ; 1456 ; 1692 ; 1714 ; 1755 + 2 ; 1756 + 4 ; 1787 ; (1828 + 3) S.E.–N.W. + 2 ; 1849 ; 1866 ; 1867 + 1 ; 1869 + 1 ; 1873 ; 1878 ; (1881 + 1) S.–N.	29

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LIENTZ, ...	Tyrol, ...	1862 + 3; 1866 + 1.	6
LIESCHACH, . . .	Carniola, ...	1882.	1
LIESENEGG, . . .	Carinthia, ...	1855; 1857 w.–e.	2
LIESER, ...	Rhenish Prussia, . .	1869.	1
LIESSING, . . .	Styria, ...	1876.	1
LIESTHAL, . . .	Bâle Canton, . . .	1836; 1855 + 4; 1863; 1870; 1871; 1878; 1881 + 3.	14
LIETZEN, . . .	Styria, ...	1857 + 11.	12
LIGERZ, ...	Berne, ...	1855.	1
LIGURIA, . . .	. . . . .	1135.	1
LIGURIAN APENNINES,	. . . . .	1882 n.–s., the centre of action in the Valley of the Trebbia.	1
LIMAVADY, . . .	Ireland, ...	1880.	1
LIMBACH, . . .	Berne Canton, . . .	1828.	1
LIMBOURG, . . .	Westphalia, . . .	1756; 1869; 1870 + 1.	4
LIMBOURG PROVINCE,	Belgium, ...	1878; 1843 + 1.	3
LIMBURG, . . .	Nassau, ...	1869 s.w.–n.e.	1
LIMBURG-EMS, . .	Nassau, ...	1869.	1
LIMNO ISLAND, . .	Grecian Archipelago, . .	*See* Lemnos.	
LIMOGES, . . .	. . . . .	1759; 1765 + 2; 1817.	5
LIMONE, ...	Cuneo, Italy, . . .	*1849* + 5, immense crevasses opened in several places, + 2; 1880.	9
LIMOUSIN, . . .	. . . . .	1684 + 3; 1759; 1780 + 3.	9
LIMPIVILLE, . . .	Goderville C., Seine Infér.,	1833.	1
LINCOLN, . . .	. . . . .	1142; 1185; 1792; 1816.	4
LINCOLNSHIRE, . .	. . . . .	1792; 1818.	2
LIND, ...	Tyrol, ...	1862.	1
LINDACH, . . .	Baden, ...	1867.	1
LINDAU, ...	Bavaria, ...	1720; 1826; 1852; 1855.	4
LINDAU, ...	Zurich Canton, . . .	1851.	1
LINDENFELS, . .	Darmstadt, ...	1867; 1869 + 3, the surface shaken elliptical, the greater axis from Lindenfels to Wiesbaden, s.w.–n.e., the lesser axis from Appenheim to Laugen; 1871 + 10 + 1 w.–e.; 1877.	18
LINDERBERG, . .	Westphalia, . . .	1863.	1
LINDOS, ...	Rhodes Island, . . .	1860 + 102.	103
LINERA, ...	Etna Acireale District, .	1880 + 8, extended to Acireale.	9
LINGSTOWN, . . .	. . . . .	1846.	1
LINGUAGROSSA, . .	Etna, Sicily, . . .	1865 + 1; 1867; 1874 + 1; 1880 + 3.	9
LINKÖPING, . . .	Ostergothland, Sweden, .	1686; 1832 + 1; 1846 + 5.	9

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LINKORO ISLAND, .	Caspian Sea, . . .	1840 + 1.	2
LINNICH, . . .	Rhenish Prussia, . . .	1873 + 2; 1874 N.–S.	4
LINTHAL, . . .	Glarus, ...	1701 + 24; 1702 + 3; 1763.	30
LINTZ, ...	Upper Austria, . . .	1770; 1785; 1837; 1848; 1865.	5
LINZ, ...	Neuwied C., Rhenish Prussia,	(1869 + 1) S.–N. + 1; 1873; 1875 + 2.	7
LIONI, ...	Naples, ...	1853.	1
LIPARI ISLAND, . .	. . . . .	*1717*; 1780; 1783; 1823; *1841*.	5
LIPHOOK, . . .	. . . . .	1833; 1834.	2
LIPOR, ...	Astrakan, Russia, . .	1785.	1
LIPPA, . . . near	Klana, Istria, . . .	1870.	1
LIPPSTADT, . . .	Westphalia, Prussia, . .	1767 W.–E.; 1878.	2
LIPTS, . . . near	Schemnitz, Hungary, . .	1845.	1
LISBON, ...	. . . . .	B. C. 377; 370; A.D. 1009; 1017; 1117; 1146; 1290, violent; *1344* + 4, and along the sea-coast; 1350; 1356 + 3; **1531** + 56; *1532*; 1551; 1575; 1597; 1598; **1699** + 3; **1724** + 2 40 leagues W. of; 1750; **1755**, great Lisbon earthquake, Nov. 1, extended to Iceland, N., Mogador, S., Tœplitz, Bohemia, E., West India Islands, W.—actual shocks were not felt over the whole of this surface, the centre of action seemingly situated in the Atlantic, a little to the W. of Portugal, + 36 + 1; *1756* + 14; 1757 + 8; 1758 + 2; 1759 + 1; 1760 + 7; **1761**; 1763; *1764*; 1765 + 1; 1768 + 3; 1769; 1770; (1772 + 2) S.–N.; *1773* S.–N. + *6*; 1777 + 1; 1780; 1781; *1783* + *2*, also at St. Jago in Galicia; 1784; 1785; 1786; 1788; 1789; 1791 + 1, very violent; 1793; 1796 + 2; **1807** + 1; 1808 + 3; 1809; 1810; *1816* N.E.–S.W. + 2, extended 300 leagues to the W.; 1818 + 3 ($1\frac{1}{2}$ leagues to W. of), + 1; 1822; 1824; 1827 W.–E. + 2; 1830 + 1; 1832; 1838; 1840; 1841 + 4; 1847 + 4; 1851 + 1; 1853 + 2; 1856 + 1; 1857 E.–W., felt at Cintra, Porto, Fox, Cadiz, Santarem, Luna, Aveiro, Vianna, Coimbre, Guimahaens, that is, the Atlantic Coast-line in the direction S.E.–N.W., + 2 E.–W. + 2; *1858* N.–S. + *1* E.–W., the strongest since 1755; 1859 E.–W.; 1862; 1863 + 1; 1865 N.E.–S.W. + 3; 1867; 1869 + 1; 1877 + 3; (1878 + 1) E.–W. + 1 + 1 E.–W.; 1880.	271
LISCATE, ...	Milan District, . . .	1786 + 3.	4
LISIEUX, ...	Calvados, ...	1853.	1
LISKEARD, . . .	. . . . .	1757; 1758; 1837; 1852; 1858; 1860.	6
LISLE, ...	Tarn, ...	1863 + 3.	4
LISMORE LIGHTHOUSE,	Oban, ...	1841.	1
LISSAC, . . . near	Klana, Illyria, . . .	1870 + 1.	2
LISSA ISLAND, . .	Dalmatia, ...	1870 N.E.–S.W. + 42 + 1 S.W.–N.E.; (1874 + 1) S.–N. + 2 + 1 S.E.–N.W.	49
LITSCHAU, . . .	Lower Austria, . . .	1855; 1857 + 2 S.–N.; 1858 S.–N. + 5 + 1 S.–N., violent, + 1 S.W.–N.E. + 1 N.–S. + 4 S.–N. + 2 S.E.–N.E. + 2 S.S.E.–N.N.W. + 33; 1860 S.–N.N.W. + 1 S.–N.W., violent, + 1 S.–N. + 23. All these shocks extended to 10 leagues N. and S.S.E. and 1 league to W. and N.W., the centre at Eulenberg, Moravia.	79

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LITTENBERG, . . .	Styria, ...	1877.	1
LIVERPOOL, . . .	. . . . .	1777 ; 1795 ; 1835 ; 1843 ; 1852.	5
LIVIDIA PROVINCE, .	Greece, ...	1853 ; 1859 ; 1861.	3
LIXURI, ...	Cephalonia, . . .	1867.	1
LJUBINJE, . . .	Herzegovina, Bosnia, . .	1882 W.–E.	1
LLANDOVERY, . .	. . . . .	1832.	1
LLANVUHANGEL, . .	. . . . .	1853.	1
LLANWREST, . . .	. . . . .	1780.	1
LOBENSTEIN, . . .	Reuss, S.W. Germany, .	1786, extended from Naila to Lobenstein ; 1872.	2
LOBSCHUTZ, . . .	Silesia, Prussia, . . .	1786 + 3 ; 1858.	5
LOCARNO, . . .	Ticino, Switzerland, . .	1868 W.–N.W. + 1 S.E.–N.W. ; 1870, W.N.W.–E.S.E.	3
LOCLE, ...	Neuchatel Canton, . .	1755 ; 1831 + 1 ; 1856 + 2, same direction as the Jura, + 2 ; (1858 + 2) E.–W. ; 1879 ; 1880 ; 1881 + 5.	19
LOCOROTUNDO, . .	Puglia, ...	1829 + 18, up to 1865 ; 1867 + 3 ; 1869 ; 1870 + 1.	26
LODI, ...	. . . . .	1781 ; 1802.	2
LOGGE, . . . near	Sienna, ...	1854.	1
LOGIERAIT PARISH, .	Perthshire, ...	1763.	1
LOGROÑO, . . .	Old Castile, Spain, . .	1817.	1
LOHMA, ...	Sieg C., Rhenish Prussia, .	1869 + 1.	2
LOIRE INFÉRIEURE, Department, ...		1812.	1
LOIRE RIVER (Lower Part of), ...		1751.	1
LOITSCH, . . .	Carniola, ...	1882.	1
LOJANO, ...	Bologna, ...	1880 ; 1881 + 3 + 1 N.E.–S.W. + 1 E.–W.	7
LÖLLING, . . .	Carinthia, ...	1878 + 1.	2
LOMBARDY, . . .	. . . . .	1040 ; 1110 + (40 shocks for forty days) ; 1117 + 4, very frequent ; 1222 ; 1255 ; 1571 ; 1642 ; 1767 ; 1837 ; 1840 ; 1851.	55
LONDON, . . .	. . . . .	1158 + 1 ; 1247 + 1 ; 1575 + 1 ; 1580 ; 1601 + 1 ; 1692 ; 1750 + 3 ; 1756 ; 1758 ; 1863 ; 1865 ; 1878.	19
LONDONDERRY, . .	. . . . .	1880.	1
LONGEAU, . . .	Haute Marne, . . .	1862.	1
LONGFLEET, . . near	Poole, ...	1834.	1
LONGJUMEAU, . .	Seine et Oise, . . .	1841.	1
LONGOBARDI, . .	Calabria, ...	1870.	1
LONGOBUCO, . . .	Calabria Citra, . . .	1824 + 3 ; 1870 ; 1871.	6
LONGRO, ...	. . . . .	1871.	1
LONGTON, . . .	. . . . .	1871.	1
LONGUÉ, ...	Maine et Loire, . .	1817.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LONGUIJON,	Moselle,	1828.	1
LONKAU VILLAGE,	Silesia,	1198 + 18, the shocks recurred for eighteen months.	19
LONS-LE-SAULNIER,	Jura,	1841 + 1; 1845; 1846; 1847 + 2; 1848; 1849; 1851; 1855 E.–W. + 1.	12
LOORANA,	Illyria,	1870.	1
LORBLE,	Klagenfurt,	1830.	1
LORCA,	Murcia, Spain,	1862; 1863 + 1; 1864 + 1.	5
LORCH,	Nassau,	1869 N.E.–S.W. + 2 N.W.–S.E. + 3.	6
LORENZANA,	Pisa,	1846 + 1, strong, 1847 + 2; 1848 + 1 + 1 S.W.–N.E.	8
LORETO,	Abruzzo Citra,	1845.	1
LORETTO,	Macerata,	1870	1
L'ORIENT,	Morbihan,	1768; 1854; 1860 W.–E.; 1866; 1868 N.–S.; 1873.	6
LORMONT,	Gironde,	1852.	1
LORRÄCH,	Baden,	1830 S.W.–N.E. + 3; (1836 + 1) S.–N.; 1855; 1862; 1863; 1869; 1878; 1879 + 1; 1881.	14
LORRAINE,		1640; 1684 + 3; 1719; 1755; 1828.	8
LORSCH,	Darmstadt,	1871.	1
LOSWITHIAL,	Cornwall,	1757.	1
LOT ET GARONNE, Department,		1815 + 3; 1854.	5
LOUBÉJAC,	Dordogne,	1850.	1
LOUGH ABER,		1870.	1
LOUGH AWE,		1818.	1
LOUGHBOROUGH,		1776.	1
LOUGH BROOM,		1867 S.E.–N.W.	1
„ DOUICH,		1880.	1
„ EARNE,		1820; 1821.	
„ FYNE,		1821.	1
„ GAIR,		1880.	1
„ GILPEAD,		1843 + 1; 1880.	3
„ NESS,		1818.	1
LOULÉ,	Algarves, Portugal,	1856 + 4.	5
LOULÉ-BOURGA,	Turkey,	1855.	1
LOURDES,	Hautes Pyrénées,	1821; 1850 + 3; 1856; 1861; 1862.	8
LOUVAIN,	Belgium,	1554 + 2; 1563; 1569; 1828 + 1; 1869.	8
LOUVIE-JUZON,	Basses Pyrénées,	1843 W.–E. + 1; (1844 + 4) E.–W.; 1846.	8
LOUZER,	Haute Garonne,	1835, violent.	1
LOVRANA,	Illyria,	1870.	1
LOVRIN,	Bannat,	1859 S.W.–N.E.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LÖWENICH, . . .	Rhenish Prussía, . .	1878 + 1.	2
LOWERZ, ...	Schwytz, ...	1844.	1
LOWESTOFT, . . .	Suffolk, ...	1864 S.E.–N.W.	1
LOWLANDMAN'S BAY, .	Jura, Scotland, . . .	1880.	1
LÜ, ...	Grisons, ...	1870 N.–S.	1
LUBAT, ...	Asia Minor, . . .	1850.	1
LUBIEH VILLAGE, .	Syria, ...	1836, completely destroyed.	1
LUBLO, ...	Hungary, ...	(1881 + 1) W.–E.	2
LUBRIN, ...	Andalucia, ...	1863 + 6.	7
LUBRING, . . .	Croatia, ...	1810 + 1.	2
LUCAR, ...	1 league from Purchena,	1772 + 1 ; 1863.	3
LUCCA, ...	[Grenada, ...	1244 ; 1414 ; **1481** + 2 ; 1740 ; 1777 ; 1828 + 1 ; 1830 + 2 ; 1839 N.W.–S.E. ; *1840*, and at Parma ; 1843 + 2 ; *1845*, E.–W. ; 1846 + 3 ; 1847 + 1 ; 1849 + 2 ; 1853 ; 1880 S.–N.	29
LUCCA, Duchy of, . .	. . . . .	1845.	1
LUCERA, ...	Capitanata, . . .	1851 ; 1852.	2
LUCERNE, . . .	. . . . .	1601 ; 1753 ; 1808 + 2 ; 1810 ; 1837 ; 1855 W.–E. + 1 ; 1856 + 2 ; 1858 ; 1880 E.–W. + 3 ; 1881.	18
LUCERNE CANTON, .	. . . . .	1721 ; 1755.	2
LUCEY, ...	On the Rhône, . . .	1840.	1
LUCIANA, . . near	Pisa, ...	1597 + 4 ; 1846.	6
LUCOLE, ...	Abruzzi, ...	1786.	1
LUDENDORF, . . .	Rheinbach C., Rh. Prussia, .	1869.	1
LUDWIGSBURG, . .	Würtemberg, . . .	1871 + 3.	4
LUDWIGSHAFEN, . .	Bavaria, ...	1869 ; 1871 + 13 ; 1881 + 1.	17
LUDWIGSTHAL, . .	Silesia, ...	(1855 + 2) W.–E.	3
LUGANO, ...	Tessin C., ...	1832 ; 1851 + 1 + 2 N.–S. ; 1853 N.–S. ; 1855 N.–S. + 1 ; 1860 ; 1879.	10
LUGANO, ...	Lake Como, . . .	1868 ; 1880.	2
LUGNANO, . . .	Tuscany, ...	1853.	1
LUGO, ...	Galicia, Spain, . . .	1844 N.–S.	1
LULEA, ...	West Bothnia, . . .	1765 + 1 ; 1869 + 2 ; 1882 + 1 N.E.–S.W.	7
LUNA, . . . near	Carrara, ...	B. C. 138.	1
LUNÉVILLE, . . .	Meurthe, ...	1843.	1
LUNIGIANA LA, . .	Tuscany, Italy, . . .	1851.	1
LUNNERN, . . .	Switzerland, . . .	1861.	1
LUNROE, ...	Norway, ...	1819 S.–N. + 25 ; 1820 + 19 ; 1821 + 3 ; 1822 + 1 ; 1823 + 16 ; 1824 + 12 ; 1825 + 7 ; 1826 + 6 ; 1827 + 37 ; 1828 + 6 ; 1829 + 7.	140
LUPOGLAVA, . . .	Croatia, ...	1880.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
LURA, ...	Portugal, ...	1841 + 2; 1857.	4
LURE, ...	Haute Saône, . . .	1862.	1
LURE MOUNTAIN, près	Forcalquier, Basses Alpes, .	1866 E.–W.	1
LUTEMBERG, . . .	Styria, ...	1838.	1
LUTRY, ...	Geneva Lake, . . .	1855.	1
LÜTSCHENTHAL, . .	Valais, ...	1857 + 1.	2
LÜTZELWIEBELSBACH,	Hesse Cassel, . . .	1869 + 2.	3
LUTZEN, ...	Carinthia, ...	1857.	1
LUTZENKIRCHEN, .	Solingen C., Rhenish Prussia,	(1869 + 2) E.–W.	3
LUXEMBOURG, . .	. . . . .	1773, extended to Vienna; 1878.	2
LUXEUIL, . . .	Haute Saône, . . .	1851.	1
LUX ST. SAUVEUR, .	Hautes Pyrénées, . .	1868; 1869 N.–S.	2
LUZ, ... near	Barrèges, ...	1835 W.–E., strong, + 1854.	3
LYCIA, ...	. . . . .	A.D. 150.	1
LYME REGIS, . . .	England, ...	1878.	1
LYON, ...	. . . . .	1682; 1755 + 1; 1766; 1770 + 1; 1791; 1814 + 1, extended to Macon and to Vienne; 1822; 1841 + 1; 1851; 1855 E.–W. + 1; 1857; 1867; 1873; 1875; 1878 + 1, extended to Geneva; 1879 S.–N.; 1881 N.–S.; 1882.	24
LYOSJANKA, . . .	Swenigorod C., Galicia, .	1880.	1
LYSCKÏHL, . . .	Sweden, ...	1851.	1
MAADAN, ...	25 miles N.W. of Nishapoor, [Persia,	1855; 1857.	2
MAASLAND, . . .	North Holland, Netherlands,	1803.	1
MACAIRE, . . .	Guyenne, ...	1750.	1
MACALABA, . . near	Girgenti, Sicily, . . .	1777 + 3, attendant on an eruption of a mud volcano	4
MACARSCA, . . .	Dalmatia, ...	(1881 + 1) S.W.–N.E.	2
M'ARTHUR'S HEAD, .	. . . . .	1880.	1
MACCHIO, . . .	Sicily, ...	1868; 1881 + 2.	4
MACEDONIA, . . .	. . . . .	62; 358; 1829 + 5, coast of, and Thrace; 1858.	9
MACERATA, . . .	. . . . .	1809; 1812 N.W. + 4; 1813; 1853; 1870.	9
MACHACOUL, . . .	Loire Inférieure, . . .	1799 + 3.	4
MACHERN, . . .	Saxony, ...	1832.	1
MACHNOWKA, . .	Kief, South Russia, . .	1821 + 2.	3
MACON, ...	Saône et Loire, . . .	1814; 1841; 1846 + 1; 1871; 1881 + 1.	7
MACRY, ...	Anatolia, ...	*1851 + 1*; 1855 + 5, sinking of village 105 feet; 1864 + 12, extended from Rhodes.	21

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MADONIA MOUNTAIN, .	Palermo, Sicily, . . .	1818 + 6, centre of disturbance at Petroli and Polizzi.	7
MADRID, ...	. . . . .	1755 + 3; 1761; 1773; 1804 + 2; 1817; 1822; 1829 + 1; 1845 + 1; (1847 + 2) N.E.–S.W. + 2; 1853 N.–S. + 2; 1854; 1856 + 1 S.–N. + 1; (1858 + 2) S.–N. and E.–W. + 3; 1880.	34
MADRID, Province, .	. . . . .	1880.	1
MAESTRICHT, . . .	Limburg, Netherlands, .	1714; 1755 + 2; 1756 + 5; 1760; 1770; 1828 + 1; 1843 + 1; 1857; 1873 + 1.	19
MAFRA, . . . near	Lisbon, ...	1858 + 1.	2
MAGDEBURG, . . .	Saxony, ...	997.	1
MAGGAROS, . . .	Transylvania, . . .	(1862 + 1) S.E.–N.W.	2
MAGNANO, . . .	Parma, ...	1881.	1
MAGNA VALLEY, . near	Bergamo, ...	1771.	1
MAGNESIA, . . .	Anatolia, ...	1845, very violent, town nearly destroyed; 1858 + 1; 1860, felt also at Smyrna; 1866; 1867 + 1; 1880, extended from Smyrna.	8
MAGNÉ, ...	Deux Sèvres, . . .	1866.	1
MAHON, ...	Minorca Island, Spain, .	(1856 + 1) E.–W.	2
MAINBURG, Margravate of,	Bavaria, . . .	1786.	1
MAIN RIVER, Valley of,	Darmstadt, ...	1876.	1
MAINSPITZE, . . .	Rhine Valley, . . .	1869.	1
MAIRA VALLEY, . .	Piedmont, ...	1808.	1
MAIS ISLAND, . .	60 miles from Rhodes, .	1864.	1
MAJORCA ISLAND, .	. . . . .	(1851 + 2) W.S.W.–E.N.E. + 5 N.N.E.–S.S.W., extended along distance of 7 leagues.	8
MAJSA, ...	Little Kumania, Hungary, .	1863.	1
MAKÓ, ...	Hungary, ...	1878.	1
MALAGA, ...	Andalucia, Spain, . .	1755; 1773; 1777 N.–S. + 1; 1790; 1804 + 14; 1841 + 1; 1843; 1851; 1852 + 2 + 2 N.–S. and E.–W.; 1856 E.–W. + 1; 1857; 1858; 1860, extended over nearly all Andalucia + 3; 1861.	38
MALATIA, . . .	Syria, ...	1158 S.–N.	1
MALBORGETH, . .	Carinthia, ...	1855 W.–E.; 1863 + 2; 1878.	5
MALCESINE, . . .	Verona, ...	1880 + 1; 1881.	3
MALEMORT, . . .	Bouches du Rhône, . .	1783 + 1.	2
MALINES, . . .	Anvers, Belgium, . .	1580.	1
MALING, ...	Dalcarlia, Sweden, . .	1829 + 1.	2
MALKAU, . . . near	Kraaden, Bohemia, . .	1860.	1
MALLERAY, . . .	Berne, ...	1881.	1
MALLOW, . . .	Co. Cork, ...	1868.	1
MALMEDY, . . .	Rhenish Prussia, . . .	1756; 1828.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MALORITZ, . . .	Upper Carinthia, . . .	1867 + 3.	4
MALSBREZEN TUNNEL,	Line of St. Peter's to Fiume, [Istria,	1870.	1
MALTA, ...	Illyria, ...	1869.	1
MALTA ISLAND, . .	. . . . .	1658 + 23 (continued for 23 days); 1692; **1693**; **1699** + 2; 1727; 1742; 1756 + 1; 1763; 1776 S.–N.; *1780* + *2*; 1790 + 1; 1804 + 1; *1810* + 2; (1818 + 1) S.E.–N.W.; also in Catania and Calabria; 1841; 1843 + 1; 1859 + 3; 1861 + 4 + 1, extended to Sicily; 1862 + 3; 1863; 1865 + 2; 1867 + 3; 1868 + 2; 1874 + 8.	82
MALTEIN, . . .	Carinthia, ...	1862 + 2; 1869 + 1.	5
MALTON, ...	. . . . .	1863; 1869 S.W.–N.E. + 2.	4
MALYJE, ...	Erivan Government, . .	1869.	1
MANAU, ...	Rhine Valley, . . .	1880.	1
MANCHESTER, . .	. . . . .	1750; 1768; 1777; 1833; 1839; 1843; 1852; 1864; 1869; 1871.	10
MANCHE, Department, de	la, ...	1843 + 3.	4
MANDAL, ...	Norway, ...	1875 + 1.	2
MANETIN, ...	Bohemia, ...	1862.	1
MANFREDONIA, . .	Capitanata, ...	1857; 1864; (1882 + 1) N.W.–S.E. + 2.	6
MANGANO, . . .	Sicily, ...	1865.	1
MANGLIS, . . .	Lat. 41° 42′ N. Long. 43° 53′ 48″ Caucasus,	1864; 1867 + 2; 1868 + 2.	7
MANGONE, . . .	Calabria, ...	1870 + 3; 1871.	5
MANHEIM, . . .	. . . . .	1728; 1756; (1776 + 1) N.W.–S.E.; 1778; 1783 + 3; 1787; (1789 + 1) N.E.–S.W.; 1825; 1869 + 8; 1871 W.–E. + 8; 1873 + 2 + 1 E.–W; 1874.	36
MAN, ISLE OF, . .	. . . . .	1786 + 1; 1788; 1843.	4
MANNSBURG, . . .	Illyria, ...	1870.	1
MANOPELLO, . . .	Basilicata, ...	1855.	1
MANOSQUE, . . .	Basses Alpes, . . .	1509; 1708, extended to Toulon, Marseilles, Sisteron, and Hyères, + 42; 1835 + 1.	46
MANS, Le, . . .	Sarthe, ...	1583; 1814 + *1*.	3
MANSFIELD, . . .	. . . . .	1817.	1
MANTINEA, Province,	Greece, ...	1867 + 1.	2
MANTUA, ...	. . . . .	1633; 1693; 1703; 1771 + 1; 1781; 1786; 1802; 1826; *1832* + *3*; 1852 + 1; 1853 + 1; 1857 + 1 E.–W.; 1864; 1868; 1870 + 1 E.–W. + 1 S.–N.	24
MAPOKA, ...	Greece, ...	1880.	1
MARADI, ...	Romagna, ...	1880.	1
MARAN, ...	North Persia, . . .	1879, town destroyed.	1
MARANOWSK Fortress, .	Caucasus, ...	1869.	1
MARASY, ...	Caucasus, ...	1869.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MARATEA, . . .	Calabria, ...	1708.	1
MARBACH, . . .	Swabian Alps, Würtemberg,	(1836 + 2) W.–E.	3
MARBURG, . . .	Styria, ...	1877 ; 1880 + 1.	3
MARBURGH, . . .	Cassel, ...	1846 ; (1869 + 3) S.–N. + 5 ; 1881 + 2.	13
MARBURG-KIRCHAIN, .	Cassel, ...	1869 + 1.	2
MARCHE, ...	Sambre et Meuse, . .	1808.	1
MARCHES, Les, . .	Savoie, ...	1856 ; 1866.	2
MARECCHIA Valley, .	Romagna, ...	1881.	1
MAREMMES, . . .	Gironde, ...	1852.	1
MARENGO Village, . .	Algeria, ...	1867.	1
MARESFIELD, . . .	Sussex, ...	1864.	1
MAREZELI, . . .	Agram District, Croatia, .	1880.	1
MARGATE, . . .	. . . . .	1831.	1
MARGONJIA, . . near	Giralt, Saros Com., Hungary,	1859.	1
MARIA FELD, . . .	Carniola, ...	1882.	1
MARIA GAIL, . . near	Villach, Carinthia, . .	1880.	1
MARIA NOSTRA, . . .	Hungary, ...	1857.	1
MARIA SAAL, . . .	Carinthia, ...	1881 N.W.–S.E.	1
MARIENBAD, . . .	Bohemia, ...	1872.	1
MARIENBERG, . .	Tyrol, ...	(1878 + 1 E.–W.	2
MARIENBERG, . .	Westerwalde, Nassau, . .	1869 + 1.	2
MARIENHEIDE, . .	Gummersbach C., Rhenish Prussia,	1869 W.–E.	1
MARING, ...	On the Moselle, . . .	1869 + 2.	3
MARINO, ...	Rome, Italy, . . .	1752 ; 1785, extended 50 miles from Rome, + 1 ; 1799 + 3 ; 1837 + 2 ; 1880.	11
MARISCO NUOVO, . .	Southern Italy, . . .	1857.	1
MARISCO VETERE, .	Southern Italy, . . .	*1857 + 5.*	6
MARIZION, . . .	. . . . .	1757.	1
MARKDORF, . . .	Baden, ...	1870 + 6.	7
MARKET-RASEN, E., .	. . . . .	1863.	1
MARKGRÖNINGEN, .	Würtemberg, . . .	1861.	1
MARKLESGRUN, . .	Bohemia, ...	1824.	1
MARKLISSA, . . .	Silesia, Prussia, . . .	1799.	1
MARKNEUKIRCHEN, .	Voigtland, Saxony, . .	1871.	1
MARKT, ...	Amt Lörrach, Baden, . .	1878 + 2 S.W.–N.E.	3
MARKTOBERLAIBACH, .	Carniola, ...	1882 + 16.	17
MARKT FRANZ, . .	Austria, ...	1869 + 3 E.–W.	4
MARLBOROUGH, . .	. . . . .	1868.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MARLEY LE ROUGET, .	Saône et Loire, . . .	1871.	1
MARLINSBRUCK, . .	Grisons, ...	1813 + 1.	2
MARMANDE, . . .	Lot et Garonne, . . .	1814 ; 1854.	2
MARMORA ISLAND, .	Sea of Marmora, . . .	1877 + 18.	19
MARMAREZZO, . .	North of Rhodes, Asia Minor,	1856 ; 1858 + 25 ; 1862, and at other points of the coast of Anatolia on the prolongation of the axis of Rhodes, + 13 ; 1864 + 1 ; 1869 ; 1871.	45
MARMORA, Sea of, . .	. . . . .	1878 + 2.	3
MARMAROS SZIGETH, .	Hungary, ...	1859 ; 1876 + 2 ; 1879 ; 1880 N.E.–S.W. + 1 S.–N.	7
MAROCCO CITY, . .	. . . . .	1719 ; 1755 ; 1848.	3
MAROCCO, Coast of, .	. . . . .	1719.	1
MAROLA, ...	Reggio Emilia, . . .	1880 N.E.–S.W.	1
MAROMME, . . .	Seine Inférieure, near Rouen,	1845.	1
MAROS SZIGETH, . .	Hungary, ...	1870.	1
MAROS-LUDAS, . .	Transylvania, . . .	1880.	1
MAROS VASARHELY, .	Hungary, ...	1871 S.E.–N.W. + 3.	4
MARQUINA, . . .	Biscay, ...	1858.	1
MARSALA, . . .	Sicily, ...	1828.	1
MARSEILLES, . . .	. . . . .	1664 ; 1708 ; 1781 ; 1783 ; 1803 ; 1808 E.–W. + 3 ; 1812 + 1 ; 1813 ; (*1818 + 1*) N.W.–S.E. + 3 ; 1820 ; 1825 + 1 ; 1828 ; 1831 ; 1841 ; 1854 + 14 N.–S. ; 1857 ; (1866 + 1) S.–N. + 1 ; 1870 + 2.	45
MARSIVAN, . . .	. . . . .	1864 + 1.	2
MARSTETTIN, . . .	Thurgau, ...	1861.	1
MARLIA, ...	Lucca, ...	1858.	1
MARTIGNY, . . .	Valais, ...	1851 ; 1881 + 4 ; 1882.	7
MARTINSBRUCK, . .	Lower Engadine, . . .	1882.	1
MARSTÓCK, . . .	. . . . .	1868.	1
MARVILLA, . . .	N.E. of Lisbon, . . .	1878.	1
MARYPORT, . . .	England, ...	1879.	1
MARZINO Valley, . .	. . . . .	1881.	1
MASCARA, . . .	Algeria, ...	1819 + 3 ; (1851 + 2) E.–W. + 2 ; 1856 ; 1872.	11
MASSA DI CARRARA, .	. . . . .	1730 + 3 ; 1740.	5
MASSA DI SOMMA, .	. . . . .	1751.	1
MASSA DUCALE, . .	Modena, ...	1852 E.–W.	1
MASSA MARITIMA, .	Tuscany, ...	1849 N.N.W.–S.S.E. ; 1851 E.–W.	2
MASSAT, ...	Ariège, ...	1852.	1
MASSIF D'ALGER, . .	Africa, ...	(1858 + 1) W.–E.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MASSOWAH,	Red Sea,	1863 + 2 ; 1864 + 3 W.–E.	7
MATERA RIVER,	Basilicata,	1845 ; 1850 ; 1851 ; 1853 ; 1858 + 2.	7
MATESA,	Terra di Lavoro,	1688.	1
MATRA,	Hungary,	1867 N.–S. + 20.	21
MATRASY,	Caucasus,	1869.	1
MATREY,	Tyrol,	1872.	1
MATRICA,	Abruzzi,	1870 + 8.	9
MAUGNAGA,	Switzerland,	1855.	1
MAULÉON,	Basses Pyrénées,	1858 ; 1874 W.–E.	2
MAURIENNE VALLEY,	Mont Blanc,	1790.	1
MAURIGLIANA,	Vesuvius District,	1867 + 1.	2
MAURON,	Morbihan,	1868.	1
MAUTERN,	Lower Austria,	1862.	1
MAVROMATI,	Messenia Prov., Greece,	1846.	1
MAXBERG,	Bohemia,	1858 N.W.–S.E.	1
MAXOU,	Rhine banks,	1880.	1
MAYANO,	Savoie,	1856.	1
MAYEN,	Eifel, Rhenish Prussia,	(1869 + 2) S.E.–N.W. + 4.	7
MAYENCE,		855 ; 858 + 1 ; 859 ; 870 ; 872 ; 880 ; *881* ; 885 ; 887 ; 1080 ; 1081 ; 1146 + 14 ; 1528 ; 1642 + 2 ; 1681 ; 1691 ; 1692 ; 1728 ; 1733 + 3 ; 1735 ; 1776 ; 1785 + 4 ; 1788 + 5 ; 1802 ; 1821 ; 1822 ; 1824 ; 1828 ; 1856 ; 1858 S.–N. + 2 ; 1869 + 15 + 3 S.S.W.–N.N.E. + 1 N.W.–S.E. + 1 W.–E. + 4 S.–N. ; 1870 + 2 ; 1871.	90
MAYENFELD,	Grisons,	1880 + 1.	2
MAYENNE,	Mayenne,	1848.	1
MAZETTA,	Abruzzo Citra,	1845.	1
MAZOA,	Pesth Com., Hungary,	1863.	1
MAZON,	Tyrol,	1862.	1
MAZZARA VALLEY,	Sicily,	1536.	1
MÉANDRE,	Isère,	1838 + 3.	4
MECCA,	Arabia,	867.	1
MECHOUNECH, near	Biskra, Algeria,	1869.	1
MECKENHEIM,	Rhenish Prussia,	(1869 + 4) W.–E.	5
MECKLINBOURG,	Duchy,	1628.	1
MEDEAH,	Algeria,	1853 ; 1858 + 2 + 1 S.E.–N.W. ; 1859 N.W.–S.E. + 2 S.W.–N.E. ; 1867 + 5 ; 1869 ; 1873 ; 1875 ; 1876 + 2.	19
MEDIASCH,	Russia,	(1829 + 3) N.W.–S.E.	4
MEDINA,	Arabia,	640 ; 650.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MEDITERRANEAN, .	. . . . .	1843, 35 miles West of Candia.	1
,, ,, . .	. . . . .	1845, long. 13° 44′ 36″ E. from Greenwich, lat. 36° 40′ 56″, three large balls of fire shot up into the air.	1
,, ,, . .	. . . . .	1855, between Sardinia Island and Coast of Africa.	1
,, ,, . .	. . . . .	1856; 1865, lat. 36° 18′ N., W. long. 2° 32′ from Greenwich.	2
MEJIDI, ...	Danube Prov., . . .	(1868 + 3) W.–E.	4
MEDOC, ...	. . . . .	1730; 1829.	2
MEERANE, . . .	Saxony, ...	1872.	1
MEGÈVE, ...	Maurienne, ...	1847.	1
MEHADIA, . . .	Croatia, ...	1881.	1
MEHADIA, . . .	Istria, ...	1871 + 14.	15
MEHLEM, . . .	Bonn C., Rhenish Prussia, .	1869 N.W.–S.E.	1
MEHREN, . . .	Nassau, ...	1869.	1
MEINIGEN, . . .	Vorarlberg, Tyrol, . .	1878.	1
MEISENHEIM, . .	Hesse Homburg, . . .	1856; 1869 + 5.	7
MEISSEN, . . .	. . . . .	1332; 1513 + 3; 1552; 1553; 1568 1720; 1862.	10
MELAZZO, . . .	20 miles North of Messina, .	1831 + 60.	61
MEL, ...	North Italy, . . .	1873.	1
MELDOLA, . . .	Forli, ...	1812; 1828 + 17; 1870 + 4.	24
MELDORF, . . .	Denmark, ...	1755.	1
MELEDA ISLAND, . .	Dalmatia, ...	1822, extended to Raqusa; 1823; 1824; *1825* + 3; (1838 + 1) W.–E.; (1839 + 1) S.–N.; 1840; 1843 + 1.	14
MELFI, ...	Basilicata, ...	*1851*, Town entirely destroyed, + 1 N.–S. + 13; 1852 + 15 + 1; 1853 + 4; 1855 + 6; 1856 + 2; 1857 + 1; 1858; 1869; 1882.	53
MELLILA, . . .	Fez, North Africa, . .	1821 + 2; 1848 + 4; 1858.	9
MELTON LODGE, . .	. . . . .	1868.	1
MEMMINGEN, . . .	Bavaria, ...	*1771* + 1.	2
MENAGGIO, . . .	Como Lake, . . .	1857.	1
MENANDER R., Valley of,	Asia Minor, . . .	1874.	1
MENDARINO CAPE, .	. . . . .	1855 + 1.	2
MENDEN, . . .	Sieg C., Rhenish Prussia, .	1869 + 2.	3
MENDIP HILLS, . .	. . . . .	1852 + 1.	2
MENDORF, . . .	Lake Constance, . . .	1851 N.W.–S.E.	1
MENDRISIO, . . .	Tessin, ...	1864; 1881.	2
MENHEIM, . . .	Solingen C., Rhenish Prussia,	1869.	1
MENIMEN, . . .	Anatolia, ...	1860, limits—N. Menimen, E. Manissa, S. Trianda, W. Torbali; 1880.	2
MENS, ...	Isère, ...	1866.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MENTÉCHÉ, . . .	Asia Minor, . . .	1869.	1
MENTONE, . . .	. . . . .	1771; 1854; 1866; 1867.	4
MEQUINEZ, . . .	Marocco, ...	1755 + 3 + 1, the town swallowed up with two Arab camps of 25,000 to 30,000 people.	5
MÉRAN, ...	Tyrol, ...	1862 S.W.–N.E., according to Boné the shock travelled from Botzen to Lihtz in 12 minutes, + 1; 1873 + 1.	4
MERCATELLO, . .	Urbino e Pesaro, . .	1385; 1810 + 25.	27
MERET OASIS, . .	25 km. from Gabes, Tunis, .	1881.	1
MERIGNAC, . . .	Gironde, ...	1852.	1
MERINGEN, . . .	Switzerland, . . .	1861, of the 26 localities where the shock was felt 21 (that is, excepting Baden, Aarau, Sakingen, Olten, and Geneva) lie in a narrow line, having a direction N.E.–S.W. through the heart of Switzerland, and the five places where the noises were heard are in the middle of this line—the shock was not remarked in the localities more usually affected by earthquakes.	1
MERKE FORT, . .	Turkestan, ...	(1865 + 1) S.W.–N.E.	2
MERSINA, . . .	Asia Minor, . . .	1863 + 1 S.W.–N.E.	2
MESSANGES, . . .	Côte d'Or, ...	1882 S.–N.	1
MESSEN, ...	Solothurn, ...	1869.	1
MESSENORCE, . .	Bulgaria, ...	1862.	1
MESSINA, . . .	Greece, ...	1867; 1870 + 1; 1876 + 1; 1878; 1881; 1882 + 3.	11
MESSINA, . . .	. . . . .	1635; 1649; 1658; 1716; 1717 + 3; 1720, simultaneously at Zurich; 1730; 1770 + 30; 1777; 1780 + 3; 1781; 1783 + 4; 1784 + 1; 1785; 1786; 1787 + 3; 1788 E.–W. + 1; 1792 + 33; 1798; 1799 + 1; 1803; 1811 + 3; 1817; 1823 + 2; 1826 + 3; 1830; 1831 + 8; 1836; 1837 E.–W.; 1838 + 1; 1839 S.E.–N. + 11; 1840 + 4; 1841 N.E.–S.W. + 9; 1843 + 1; 1844 + 4; 1846 + 8; 1848; 1850 + 39; 1851; 1852 + 73; 1854; 1857; 1866; 1867 S.–N. + 1; 1869; 1870.	293
MESOPOTAMIA, . .	. . . . .	550; 678; 749; 1058; 1138; 1201; 1204.	7
MESSENIA PROVINCE, .	Greece, ...	1846 + 3.	4
METHENHEIM, . .	Darmstadt, ...	1869 + 4.	5
METIDJA LA, . . .	Algeria, ...	1865 + 2; 1867 + 1.	5
METKOWICH, . . .	Dalmatia, ...	1881 N.E.–S.W. + 1; 1882 N.–S. + 1 N.–S.	4
METLOVIC, . . .	Dalmatia, ...	1876 + 6.	7
METTERNICH, . .	Euskirchen C., Rh. Prussia,	1869 + 2.	3
METZ, ...	. . . . .	1672; 1756; 1828; 1846; 1855 N.–S.	5
MEUDON, . . .	Seine, ...	1869.	1
MEUDON, . . .	Switzerland, . . .	1846.	1
MEUILLY, . . .	Côte d'Or, ...	1882 S.–N.	1
MEULAN, . . .	Seine et Oise, . . .	(1841 + 2) N.–S.	3
MEUSE, Lower, . .	. . . . .	1803.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MEUSE VALLEY,		1828.	1
MEVAGISSEY,	Cornwall,	1860.	1
MEYRINGEN,	Berne Canton,	1840 + 2 S.E.–N.W. + 1 ; 1856 + 1 E.–W. + 1 ; 1880.	8
MEZEL,	Basses Alpes,	1863.	1
MEZIÈRES,	Ardennes,	1755.	1
MEZIÈRES, near	Aigle, Vaud Canton,	1880 + 1.	2
MEZZO,	Ragusa,	1760.	1
MIANE,	Treviso Province,	1859.	1
MIANEH,	North Persia,	1879.	1
MICHELNEY,	Parret Valley,	1868.	1
MICHELSTADT,	Darmstadt,	1878.	1
MICROMANI,	Messenia Province, Greece,	1846.	1
MIDDLE,		1868.	1
MIDDLEBOURG, / MIDDLEBURG,	Walchern Island, Netherlands,	1828 ; (1848 + 3) N.E.–S.W.	5
MIDDLETON,		1820 ; 1869.	2
MIEHLEN,	Nassau,	1869 + 1.	2
MIES,	Bohemia,	1822.	1
MIGNANO,	Terra di Lavoro,	1765 + 1.	2
MIKLAUTZHOF,	Carinthia,	1880.	1
MILAN,		1473 ; 1521 + 1 ; 1703 + 1 ; 1740 ; 1751 ; 1755 + 2 ; *1757*, extended to Syracuse ; *1759 + 1* ; 1780 ; 1781 ; 1786 + 1 ; 1802 ; 1808 ; 1818 + 1 ; *1832* + 3 ; 1834 N.W.–S.E ; 1837 E.–W. ; 1838 ; 1840 ; 1851 + 1 S.–N. ; 1853 S.–W. ; 1855 E.–W. + 2 N.–E. + 2 N.E.–S.W. ; 1855 N.E.–S.W. + 1 ; 1857 ; 1864 ; 1879 ; 1880 ; 1882.	44
MILAN, Duchy of,		1661.	1
MILAZZO,	Sicily,	1717 ; 1786 ; 1831.	3
MILETO,	Calabria,	1659 ; 1869.	2
MILHAU,	Aveyron,	1855.	1
MILIANEH,	Algeria,	1853 ; 1858 + 2 ; 1867 E.–W. ; (1874 + 1) N.–S. + 1.	8
MILITELLO,	Sicily,	1693 ; 1866.	2
MILLESIMO,	Constantine Province, Algeria,	1850 ; (1867 + 1) W.–E.	3
MILLIÈRES,	Maurienne,	1847.	1
MILO,	18 miles from Catania, Sicily,	1832 + 1 ; 1868.	3
MILO ISLAND,	Greece,	(1871 + 506) W.–E., crevasse opened E.–W., + 3.	510
MIMOISCA,	Poland,	1767.	1
MINBACH,	Tyrol,	1848.	1
MINCIO River, Course of,		1851.	1
MINEO,	Etna,	1880 ; 1881 + 5.	7

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MINERVINO,	Barri Province,	1851.	1
MINIANO, near	Naples,	1765.	1
MINKSYSK,	Don Cossacks,	*1816 + 1.*	2
MIRABEAU, près	Beaumont Vaucluse,	1858; 1859.	2
MIRABEAU,	Côte d'Or,	1862.	1
MIRABELLA,	Principato Ultra,	1688.	1
MIRABELLE,	Drôme,	1812 + 2.	3
MIRAMAR,	Istria,	1882 + 2.	3
MIRIBEL,	Ain,	(1857 + 3) S.–N.	4
MISSIMARÉ,	Sicily,	1876.	1
MISSOLONGHI,	Greece,	1860, felt simultaneously at Athens, Tripoli, Kalamata, and Kalamaki, + 1; 1861; 1867 E.–W.; 1882 + 1.	6
MISTEEK,	Brandenbourg, Prussia,	1785; 1786.	2
MISTELHOLZ,	Bohemia,	1880.	1
MISTELHOLZKOLLERN,	,,	1880.	1
MISTRELLA,	Messina, Sicily,	1867 + 2; 1880.	4
MITIDJA,	Algeria,	*1867.*	1
MITTELGEBIRGE,	Tyrol,	1880.	1
MITTENWALD,	Bavaria,	(1819 + 1) S.–N.; 1880 N.–S.	3
MITTERDORF,	Styria,	1876 E.–W.	1
MITTERFELS,	Bavaria,	1840.	1
MITWEIDA,	Upper Saxony,	1821; 1857; 1869.	3
MODANE,	Savoie,	1881 + 1.	2
MODAUTHAL,	Darmstadt,	1871.	1
MODENA,		1268; 1348; 1353; 1399; 1501 + 3; 1570 + 84; 1661; 1753; 1771 + 1; 1774 N.–S. + 1; 1796; 1818; 1831 + 2; 1836; 1844 + 2; 1845 + 1; 1847; 1849; 1850; 1852; 1857; (1860 + 3) N.N.W.–S.S.E. + 1; 1864 + 1 + 1 E.–W.; 1866; 1869, violent; 1871 E.–W.; 1873 + 1; 1880 + 1.	131
MODENA, DUCHY OF,		1845.	1
MODICA, near	Syracuse,	1825 + 1; 1861.	3
MODIGLIANA,	Romagna,	1781; 1854; 1881 + 1 N.–S.	3
MODRA,	Hungary,	1866.	1
MŒGLSBERG,	Sweden,	1851.	1
MŒLSBERG,	,,	1851.	1
MOEL VALLEY,	Carinthia,	1862.	1
MŒN ISLAND,	Denmark,	1869.	1
MOETLING,	Carniola,	1866; 1881 E.–W. + 1.	3
MOGADOR,		1755.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MOHACS,	Hungary,	1876 N.E–S.W.	1
MOISSAC,	Tarn et Garonne,	1743 + 1.	2
MOKHA,	Red Sea,	1861 + 3.	4
MOKRIN,	Servian Woiwod, Austria,	1879 + 1.	2
MOKRITZ, near	Jerrentz, Carniola,	1879 N.–S. + 1.	2
MOLA,	Gaeta Gulf,	1725 + 3.	4
MOLD,		1782.	1
MOLDAVIA,		1802 ; 1838 + 2 ; 1879 + 5 ; 1880 S.W.–N.E.	11
MOLDAWA,	Croatia,	1879 E.–W. + 66, centre of action in an island lying near Alt Moldawa, and extending to Babagay—the surface of the island was deeply crevassed, and water projected from the crevasses, flooding the island, ending with a discharge of sand and earth, + 4.	71
MOLESY, E.,		1750.	1
MOLFETTA,	Terra di Barri,	1856.	1
MOLISE PROV.,		1805 + 2 ; 1807 ; 1821 E.–W. + 7 ; 1853.	13
MOLIVO,	North of Metylin,	1865.	1
MOLLA GASPER,	Russian Armenia,	1871.	1
MOLLIS,	Glaris C.,	1702 ; 1705 + 1 ; 1871 + 1.	5
MOLOKISCHI,	Balta C., Podolia,	1880.	1
MOMBACH,	Darmstadt,	1869 + 4.	5
MOMENHEIM,	Rhenish Hesse,	1869 + 3 + 1 S.–N.	5
MONACH,	Scotland,	1880.	1
MONACO,		1771.	1
MONASTER = BITOLIA,	Rumili, Turkey,	1851 ; 1856 ; 1858 + 8 ; 1871 + 1.	13
MONCALIERE,	Piedmont,	1866 S.E.–N.W. ; (1868 + 1) N.–S. ; 1870 ; 1881.	5
MONCORVO,	Portugal,	1858 ; 1863.	2
MONDAVIO,	Urbino e Pesaro,	1829 + 1.	2
MONDOVI,	Piedmont,	1855 + 3 ; 1866.	5
MONDRAGONE,	Terra di Lavoro,	1882 + 1.	2
MONEMVASIA,	Peloponnesus,	1859.	1
MOUEH,	Armenia,	1871.	1
MONFALCONE,	Istrian Coast,	1882 + 2.	3
MONGIANA,	Calabria,	1865 + 3.	4
MONISTROL SUR LOIRE,	Allièr,	(1859 + 1) E.–W.	2
MONMOUTHSHIRE,		1839 ; 1865.	2
MONOPOLI,	Terra di Barri,	1855.	1
MONOR,	Hungary,	1826.	1
MONOSTOR,	,,	1868 + 13.	14

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MONS, ...	. . . . .	1756 ; 1828.	2
MONSELICE, . . .	Venice, ...	1870 + 5.	6
MONTABOUR, . . .	Nassau, ...	(1858 + 2) E.–W. ; 1809 S.W.–N.E.	4
MONTAFON Valley, .	Tyrol, ...	1826.	1
MONTAIGU, . . .	Loire Inférieure, . . .	(1877 + 1) N.E.–S.W.	2
MONTALCINO. . .	Sienna, ...	1849.	1
MONTALE, . . .	Firenze, ...	1768 + 1.	2
MONTALTO, . . .	. . . . .	1869 + 2.	3
MONTALTO DI CHIERI,	Torino, ...	1808.	1
MONTALUCIO, . .	Tuscany, ...	1851.	1
MONT BARD, . . .	Côte d'Or, ...	1755 ; 1783 ; 1866.	3
MONTBELIARD, . .	Doubs, ...	1845.	1
MONT BLANC District, .	. . . . .	1802 ; 1804.	2
MONT BRISON, . .	Loire, ...	1808.	1
MONT CENIS, . . .	. . . . .	1753 ; 1882 + 1.	3
MONT DAUPHIN, . .	Hautes Alpes, . . .	1766 ; 1773 N.–S. ; 1780 S.–N. ; 1785 + 1.	5
MONT DE MARSAN, .	Landes, ...	(1862 + 1) S.W.–N.E.	2
MONT DIDIER, . .	Somme, ...	1756.	1
MONT D'OR, . . .	Ardèche et Gard, . . .	1770 + 1 ; (1863 + 17) N.–S. + 17, felt at Besses, Bagnolis, Murolo, Aylat, Orcival, Clermont, + 3.	40
MONTE BALDO, . .	Lago di Garda, . . .	1866 + 77 ; 1868 + 1 ; 1880 + 1 ; 1881.	83
MONTE CASSINO, . .	Terra di Lavoro, . . .	1120 ; 1881 + 2 ; 1882.	5
MONTE CATINI, . .	. . . . .	1846.	1
MONTE CAVO, . .	Albano Mountains, Rome, .	1881 + 1.	2
MONTECCHIO, . .	Este Territory, . . .	1834.	1
MONTE CHIARAGOTO, .	Parma, ...	1834.	1
MONTEFALCO, . .	Perugia, ...	1740 + 3 ; 1832.	5
MONTE FALCONE, . .	Umbria, ...	1878 + 3.	4
MONTE FORTINO, . .	Velletri, ...	1850 ; 1880 ; 1881.	3
MONTE FRASCONE, .	Viterbo, ...	1695 ; 1881 W.–E.	2
MONTE FRUMENTI, .	. . . . .	1865 + 27, extended to Fossaccia.	28
MONTE GEORGIO, . .	Velletri, ...	1880.	1
MONTE GIULIANO, .	Padua Territory, . . .	1861.	1
MONTE JEGO, . . near	San Sepolero, . . .	1871.	1
MONTE LEONE, . .	Calabria, ...	1730 + 3 ; 1783 ; 1788 ; 1826 ; 1832 + 1 ; 1841 ; 1845 ; 1850 + 3 ; 1852 + 3 ; 1861 ; 1869 N.–S. + 46 ; 1870 + 2 ; 1881.	70
MONTELIMAR, . .	Drôme, ...	1773 + 1 + 1 N.W.–S.E.	3
MONTE LOPIALE, . near	Rome, ...	1837 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MONTE MAJELLO, . .	Abruzzo Citra, . . .	1840 + 3.	4
MONTE MURRO, . .	Basilicata, ...	1857 + 8, violent, + 6 ; 1856 + 6.	22
MONTENEGRO, . .	. . . . .	1877 ; 1880.	2
MONTENERO, . .	Molise, ...	1781.	1
MONTENOTTE, . .	Algeria, ...	1873 N.E.–S.W.	1
MONTEPIANO, . .	Abruzzi, ...	1765.	1
MONTEPORZIO, . .	Urbino e Pesaro, . . .	1801 ; 1833 ; 1855 ; 1873.	4
MONTEPULCIANO, . .	Arezzo, ...	1775 ; 1849 + 5 + 2 N.–S. ; 1851 + 1 ; 1854 ; 1861 + 1 S.E.–N.W. + 3.	17
MONTERDE, . . .	Aragon, ...	1851.	1
MONTEROBORDE, . .	Roman States, . . .	1786.	1
MONTE ROSA, . .	. . . . .	1881.	1
MONTE ROSSO, . .	. . . . .	1869.	1
MONTE ROTONDO, . .	25 miles from Sienna, Grossetto,	1859.	1
MONTE ROTONDO, . .	Rome, ...	1824.	1
MONTE SAN ANGELO, .	Capitanata, ...	1849 ; 1850 + 1 ; 1864.	4
MONTE SANO, . .	Campania, ...	*1857 + 5.*	6
MONTE SAN VICINO, .	Macerata, ...	1849 + 1.	2
MONTESCUDAJO, . .	Pisa, ...	1846 + 1 ; 1871 + 1.	4
MONTE STATI, . .	Piedmont, ...	1814.	1
MONTE VARCHI, . near	Florence, ...	1846 ; 1858.	2
MONTE VISO, . . .	. . . . .	1808.	1
MONT FAUCON, . .	Languedoc, ...	1840.	1
MONTFORT L'AMAURY,	Seine et Oise, . . .	1760 E.S.E.–W.N.W. + 3.	4
MONTHAUSER, . .	Upper Austria, . . .	1868 + 1 ; 1869 + 1.	4
MONTHOUTON, . .	Doubs, ...	1857.	1
MONTIGNAC, . . .	Charente, ...	1864 + 1.	2
MONTIGNY SUR VINGEANNE,	Côte d'Or, ...	1862.	1
MONTJOIE, . . .	Rhenish Prussia, . . .	1878.	1
MONT LOUIS, . . .	Pyrénées Orientales, . .	1821.	1
MONT LUÇON, . .	Allier, ...	1857 ; 1866 + 1.	3
MONTLUEL, . . .	Ain, ...	(1857 + 3) S.–N.	4
MONTMARAULT, . .	Allier, ...	1854 ; 1879.	2
MONT MELIAN, . .	Savoie, ...	1856.	1
MONTMORENCY, . .	Seine et Oise, . . .	1769.	1
MONTPELIER, . .	Hérault, ...	1374 + 3 ; 1397 ; 1427; 1750 ; 1808 ; (1854 + 1) N.N.E.–S.S.W.	10
MONTREUX, . . .	Vaud Canton, . . .	1805 ; 1877 ; 1880 ; 1881 + 3.	7
MONTRICHARD, . .	Loire et Cher, . . .	1855.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MONTROND, . . .	Savoie, ...	1840 + 1; 1844 + 8 + 1, extended to St. Jean de Maurienne.	12
MONT ST. HELIE, . .	Messenia, Greece, . .	1829.	1
MONT ST. JEAN, . .	Côte d'Or, ...	1838.	1
MONT ST. MICHAEL, .	. . . . .	1155.	1
MONT ST. VINCENT, .	Saône et Loire, . . .	1871.	1
MONT VILLIERS, . near	Hâvre, ...	1847 W.–E.	1
MONZALEONE, . .	. . . . .	1851.	1
MONZEL, ...	Mosellethale, . . .	1869.	1
MOOR, ...	Hungary, ...	1810 + 8; 1811 + 1; 1820 + 3; 1856 E,W. + 5; 1863; 1866 + 1.	24
MOOS, ...	Norway, ...	1834.	1
MOOSBRUNN, . . .	. . . . .	1872.	1
MOOSBURG, . . .	Carinthia, ...	1881 S.W.–N.E.	1
MORASTAND, . . .	Sweden, ...	1858 + 1.	2
MORA, ...	Toledo District, . . .	1755 + 4.	5
MORAT, ...	Fribourg, ...	1855 S.–N.	1
MORAVIA, . . .	. . . . .	1556; 1590; 1785; 1786 + 1; 1858; 1864 S.E.–N.W.; 1876.	8
MORAWICKA, . . .	Silesia, ...	1785.	1
MORBEGNO, . . .	Adda Valley, . . .	1851.	1
MORBIHAN Department,	. . . . .	1859.	1
MORBIO, ...	Ticino Canton . . .	1819.	1
MORCA, ...	. . . . .	1714; **1750**; 1753; *1756 + 1*, a new island upraised; *1804 + 1*; 1805; 1817 + *8*; 1820 S.E.–N.W. + 2; 1821; 1837.	22
MORECAMBE BAY, .	. . . . .	1867.	1
MORGES, ...	Vaud Canton, . . .	1601; 1650 + 1; 1716 + 3; 1846; 1876 + 3 1878; 1879 + 2; 1880; 1881 + 4; 1882.	23
MORIAGO, . . .	Treviso Province, . .	1859.	1
MORLENBACH, . .	Darmstadt, ...	1869 + 4; 1873 + 2; 1874; 1875.	10
MORNAY, . . .	Côte d'Or, ...	1862.	1
MOROBITZ, . . near	Gottschee, Illyria, . .	1870 W.–E.	1
MORS, ...	Sweden, ...	1823.	1
MORSBACH, . . .	Waldbrœl C., Rh. Prussia, .	1869 + 2.	3
MORTAGNE, . . .	Orne, ...	1775; 1827.	2
MORTARA, ...	Sicily, ...	1865.	1
MORCHGANZEN, . .	Styria, ...	1880.	1
MOSCOW, . . .	. . . . .	1802.	1
MOSDOCK, . . .	On the Terck, . . .	1785 + 3.	4
MOSEL, OBER, . .	Rhenish Prussia, . .	1869 + 3.	4

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MOSELLE Valley, . .	. . . . .	1828.	1
MOSTAGANEM, . .	Algeria, ...	1857 ; 1860 + 2 ; (1862 + 1) s.w.–n.e. ; 1871 + 3 ; 1872.	11
MOSTANJE, . . .	Illyria, ...	1870.	1
MOSTAR, ...	Dalmatia, ...	1853 ; 1876 + 6 + 1.	9
MOTHERWELL, . .	. . . . .	1880.	1
MOTRIL, ...	Andalucia, ...	1804 + 16, extended to the sea, + 7 ; 1863.	25
MONTRONE, . . .	. . . . .	1847.	1
MOTTE SERVOLEZ, .	Savoie, ...	1856.	1
MÖTTLING, . . .	Lower Carinthia, . .	(1881 + 1) e.–w.	2
MOTZ, ...	Savoie, ...	1818.	1
MOUILLERON en Pareds,	Vendée, ...	(1864 + 2) w.–e.	3
MOUKRAVANE, . .	Caucasus, ...	1867.	1
MOULA, ...	Anatolia, ...	1869.	1
MOUNTS BAY, . .	. . . . .	1847.	1
MOURZOUK, . . .	Fezzan, ...	1853 + 3.	4
MOURFATLAR, . .	Danube Province, . .	1868 w.–e. + 3.	4
MOUTIERS, . . .	Basses Alpes, . . .	1804 + 3 ; 1847 + 1 ; 1855 e.–w. + 4, centre at St. Sauveur ; 1856 + 4 ; 1863 + 2 ; 1865 + 3 + 1 n.–s.	24
MOUZAIAVILLE, . .	Algeria, ...	1867 + 10 + 1 n.–s. ; 1869 ; 1870 ; 1873 n.–s.	15
MOZDOK, ...	Caucasus, ...	1861.	1
MTSKHITHA, . . .	Caucasus, ...	1283 + 4.	5
MUGELLO, The, . .	. . . . .	1335 ; 1722 + 3 ; 1762 + 21 ; 1849 + 6 ; 1864 + 12.	47
MUHALETSCH, . .	Asia Minor, . . .	1850.	1
MÜHLE, ...	Berne, ...	1869.	1
MUHLHAUSEN, .	Thuringia, Saxony, . .	1368 ; 1830 + 3 s.w.–n.e.	5
MÜHLHAUSEN, . .	Alsace, ...	1721 ; 1755 ; 1767 ; 1835 ; 1837 e.–w. ; 1847 ; 1855 s.w.–n.e. ; 1859 + 1 ; 1877 ; 1879 + 1 ; 1881 + 1.	14
MUHLBACH, . . .	Würtemberg, . . .	(1867 + 2) n.e.–s.w.	3
MUHLEHORN, . . .	Glarus Canton, . . .	1763 + 50, 50 shocks between 1763 and May, 1764.	51
MULHEIM = MUHLHEIM,	Baden, ...	1812 ; 1824 ; (1830 + 3) s.w.–n.e. ; 1853 + 1	8
MULHEIM = MUHLHEIM,	Cleveberg, ...	1823 ; 1853.	2
MULHEIM = MUHLHEIM,	Rhenish Prussia, . . .	1878 s.s.w.–n.n.e.	1
MULL ISLAND, . .	. . . . .	1877.	1
MUMBUG THAL, . .	Rhenish Prussia, . . .	1869 + 2 s.–n. + 1.	4
MÜNCHBERG, . . .	Fichtelgebirge, Bohemia, .	1824.	1
MUNCHWEILEN = Munchwyl,	Thurgau C., Switzerland,	1851.	1
MUNDERFING, . .	Austria, ...	1877.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
MUNICH, ...	. . . . .	1572 ; 1750 + 2 ; 1755 ; 1787 + 1 ; 1819 ; 1836 ; 1872 ; 1873.	11
MUNSINGEN, . . .	Würtemberg, . . .	1828 ; 1830 + 1.	3
MUNSTER, . . .	Lüneburg, Hanover, . .	1767 ; 1878.	2
MUNSTER, . . near	Dieburg, Darmstadt, . .	1869 + 2.	3
MUNSTER AM STEIN, .	Kreutznach C., Rh. Prussia,	1869.	1
MUNSTERLINGEN, . .	Thurgau, Switzerland, .	1858.	1
MUNSTERMAYFELD, .	Coblentz C., Rh. Prussia, .	1869 + 3 + 1 W.–E. + 1 N.–S.	6
MUNSTERTHAL, . .	Baden, ...	1829 ; 1843.	2
MUOTTATHAL, . .	Schwytz Canton, . . .	1881.	1
MURAT, ...	Cantal, ...	1873 S.W.–N.E.	1
MURCIA, KINGDOM OF, .	Spain, . . .	*1672* ; 1804 ; 1822 + 3 ; 1828 + 4 ; 1829 + 178 ; 1844 + 1 ; 1856 ; 1860 ; 1861 ; 1863.	196
MURCIA, ...	Spain, ...	1822 ; 1828 N.W.–S.E. + 308 ; 1829 + 10 ; 1830 ; *1837* N.–S. ; 1845 ; 1846 + 2 ; (1855 + 5) E.–W. + 4 ; (1856 + 4) E.–W. + 1 ; 1861 + 1 ; 1863 + 2 ; 1864 + 1 ; 1867 + 7 ; 1874 + 1.	359
MUREK, ...	Styria, ...	1855 N.E.–S.W.	1
MURO, ...	Basilicata, ...	1858.	1
MUROLS, ...	Puy de Dôme, . . .	1863 + 2.	3
MURRAU, ...	Styria, ...	1865 N.W.–S.E. + 1 ; 1881 S.W.–N.E.	3
MURZTHAL, . . .	Styria, ...	1865.	1
MURZZUSCHLAG, . .	Styria, ...	1811 W.–E. + 3 ; 1829 ; 1830 + 1 ; 1847.	2
MUSCEL DISTRICT, . .	North of Balkans, . .	1879 + 1.	2
MUSINGIN BAILIWICK, .	Swabian Alps, . . .	(1830 + 2) W.–E.	3
MYRDALIN, . . .	Iceland, ...	1721 ; 1755, very violent.	2
MYRDALS JOKUL, . .	Iceland, ...	1860.	1
MYTELENE ISLAND, .	. . . . .	1383 + 2, very violent ; 1688 ; 1754 ; 1755 ; *1826* + 1, also at Smyrna ; 1845 + 58 ; 1846 + 13 ; 1852 ; 1855 + 1 E.–W. ; 1856 + 11 ; 1859 + 2 ; 1860 + 8 ; 1862 ; 1865 N.–S. + 2 + 1 W.–E. ; 1867, and part of Anatolia, + 1 N. 10° E.–S. 10° W., + 3, violent, + 46 ; 1868 + 3 ; 1880 ; 1881.	170
NABRESINA, . . .	Istrian Coast, . . .	1882 + 2.	3
NADAS, ...	Presbourg Com., Hungary, .	1869 + 3 ; 1870 + 1.	6
NAGO, ...	Tyrol, ...	(1870 + 2) S.W.–N.E.	3
NAGY-BEREZEMA, . .	Hungary, ...	1880.	1
NAGY-CALLO, . . .	,, ...	1864 N.W. + 1.	2
NAGY-KANISKA = GROSS KIRCHEN,	Hungary, . . .	1876 + 1.	2
NAGY KAROLY, . .	,, ...	(1829 + 4) N.E.–S.W. + 3 ; 1859 ; 1865.	10
NAGY-KÆRŒS, . .	Hungary, ...	1863 ; 1865 + 2.	4
NAIRNS, ...	Switzerland, . . .	1871.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
NAKHITCHEVAN, . .	Caucasus, ...	1841 ; 1848 + 9.	11
NAMSDORF, . . .	. . . . .	1872.	1
NAMUR, ...	. . . . .	1640 ; 1756 + 1 ; 1828 ; 1878 + 1.	6
NANCY, ...	. . . . .	1682 ; 1846 ; 1855 N.–S.	3
NANTES, ...	. . . . .	1588, extended to Saumur ; 1715 ; 1750 ; 1767 ; 1799 + 2 ; 1803 ; 1812 ; 1814 ; 1822 ; 1835 S.E.–N,W. ; 1836 ; 1840 + 1 ; 1842 ; 1843 + 1 ; 1844 ; 1852 ; 1853 S.E.–N.W. + 1 ; 1862, extended 2 leagues down the river, + 1, R. = 20 km.	23
NAPLES, Kingdom of, .	. . . . .	1253 ; 1268 ; **1450** ; **1456** + *2*, there perished 60,000 people ; 1523 + 3 ; 1537 + 2 ; 1550 + 2 ; 1559 ; 1561 + 3 ; **1601** ; 1609 ; 1665 ; 1666 ; 1694 ; 1720 ; 1725 + 1 ; **1732** ; 1744 ; 1806 + 1 ; 1840 ; *1841* + 14 + 2 S.–N. ; 1842 ; 1843 + 2 ; 1845 ; 1852 ; 1858 ; 1859 + 1 ; 1877.	61
NAPLES, ...	. . . . .	A.D. 63 ; 1180 ; 1248 ; 1282 ; 1343 ; 1348 ; 1406 ; 1426 ; 1448, some thousands perished ; 1466 ; 1486 ; 1538 + 20 ; 1551 + 3 ; 1582 ; 1594 ; 1616 + 1 ; 1626 ; 1631 + 20 ; 1632 + 9 + 120, continuous for 4 months ; 1633 + 3 ; 1649 ; 1657 ; 1687 + 2 ; 1688 + 3, and many other places along the Appenines as far as Mutese in the North, and Mirabella and Benevento in the South ; 1694 + 1 ; 1697 ; 1703 + 1 ; 1704 ; *1726* + *6* ; 1724, extended to Swabia and to England ; 1730 + 1 ; **1731** + 3 ; 1732 ; 1733 + 3 ; 1739 ; *1740* ; 1742 ; 1750 + 1 ; 1751 + 5 ; 1753 ; 1754 ; 1755 ; 1756 ; *1758* + *1* ; 1759 ; 1760 + 1 ; 1761 + 1 ; 1766 ; 1767 + 2 ; 1768 ; 1777 ; 1779 E.–W. + 1 ; 1782 ; 1784 + 1 ; 1785 + 3 ; 1786 ; 1787 + 1 ; 1788 ; 1794 ; 1802 ; 1805 N.–S. + 5 + 1 ; 1806 ; 1810 + 1 ; 1813 ; 1814 + 1 ; 1817 + 3 ; 1821 + 1 ; 1822 + 1 ; 1826 + 1 ; 1832 ; 1835 ; 1836 + 1 ; 1838 + 1 ; 1840 ; 1841 + 2 ; 1843 + 4 ; 1844 + 1 ; 1846 + 3 ; 1851 + 3 ; 1853 W.–E. + 3, extended from Solopace along the line of Caserta and Nola ; 1854 ; 1856 + 14 ; 1857 + 8 + 90, from 6th Dec. ; 1858 + 12 ; 1861 + 1 ; 1865 E.–W. + 12 ; 1867 + 2 ; 1868 + 3 ; 1869 N.W.–S.E. + 1, extended along the coast to St. Angelo, Potenza, Melfi, + 3 ; 1870 + 3 N.W.–S.E. + 1 ; 1871 + 3 ; 1872 + 2 ; 1875 N.–S. ; 1878 + 4 ; 1879 + 3 ; 1880 + 3 ; 1881 + 3 ; 1882.	512
NAPOLEON VENDÉE =	Bourbon Vendée, . .	1852 N.W.–S.E.	1
NAPLOUSE, . . .	. . . . .	(1870 + 1) W.–E.	2
NARBONNE, . . .	. . . . .	1660 ; 1750 ; 1854.	3
NARDO, ...	Otranto Province, . .	1245 ; 1350 ; 1395 ; 1743.	4
NARENTA VALLEY, .	Dalmatia, ...	1882.	1
NARNI, ...	. . . . .	1703 ; 1880 + 2.	3
NARSIA, ...	. . . . .	B.C. 103.	1
NARWA, ...	Baltic Province, Russia, .	1881, the surface shaken extended from Narva, W. 13 km. ; E. 21 km. ; S. 15 km. ; N. 10 km., + 1.	2
NASILDI, ...	Aidin Province, Turkey, .	1855 + 5.	6
NASO, ...	Sicily, ...	1631 ; 1736 ; 1739, very violent ; 1823.	4
NASNEM, ...	Caucasus, ...	1874 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
NASSAU, ...	. . . . .	1878.	1
NASSENFUS, . . near	Laybach, Carinthia, . .	1871 + 60 + 3 N.W.–S.E. + 2 S.E.–N.W. ; 1874 + 9 + 3 S.W.–N.E. + 1 S.E.–N.W. ; 1881 ; (1878 + 1) S.E.–N.W. + 1.	84
NASWAN FORTRESS, .	Caucasus, ...	1860 + 6.	7
NATERS, ...	Valais, ...	1855 ; 1860 ; 1862 ; 1863 + 4.	8
NATHAIR, . . .	. . . . .	1750.	1
NATOLIA, . . .	Turkey, ...	1719.	1
NAUDERS, . . .	Lower Engadine, . .	1867 ; 1868 S.E.–N.W.	2
NAUENAHR, . . .	Coblentz Prov., Rh. Prussia,	1869.	1
NAUHEIM, . . .	Hesse, ...	1846 + 2.	3
NÄUNSTADT, . . .	6½ leagues from Christiania, [Norway,	1846 N.N.W.–S.S.E. + 2.	3
NAUPAKTOS, . . .	Lepanto Gulf, . . .	1857 ; 1858 + 29.	31
NAUPLIA, . . .	Peloponnesus, . . .	1830 + 4 ; 1836 ; 1841 + 1 ; 1866 E.–W. ; 1867.	10
NAVARREUX, . . .	Basses Pyrénées, . .	1802 ; 1852.	2
NAXOS ISLAND, . .	. . . . .	1508.	1
NAY, ...	Basses Pyrénées, . .	1777 + 1 ; 1779.	3
NAZLI, ...	Anatolia, ...	1862 + 1 ; 1863 E.–W.	3
NAZRANOWSK, . .	Caucasus, ...	1860 + 5.	6
NEAPOLITAN COAST, .	. . . . .	1392.	1
NEATH, ...	. . . . .	1832.	1
NECKAR, UPPER, . .	Würtemberg, . . .	1872.	1
NECKARGEMÜND, . .	Baden, ...	1871 S.–N.	1
NEGRALS, . . .	Alicante Province, . .	1856 + 2.	3
NEGROPONT ISLAND, .	*See* Eubea Island, . .		
NEISSE, ...	Silesia, Prussia, . . .	1786 + 3.	4
NEMOURS, . . .	Algeria, ...	1871 + 3.	4
NEO-CÆSAREA, . .	Pontus, ...	127 ; 343, the city ruined ; 366 ; 499.	4
NESME, ...	Norway, ...	1871 + 22.	23
NESPES, ...	Croatia, ...	(1860 + 3) N.–S. ; 1867 N.–S.	5
NESTEMBACH, . .	Bavaria, ...	1755.	1
NESS, ...	. . . . .	1880.	1
NESSLAU, . . .	Switzerland, . . .	1861.	1
NETHERLANDS, . .	. . . . .	1580 ; 1601, violent ; 1802 ; 1804.	4
NETHY, . . . near	Southampton, . . .	1878.	1
NETHERLANDS, Coast of,	and English, . . .	1134.	1
NEU BREISACH, . .	Haut Rhin, . . .	1801.	1
NEUDEY, ...	Carniola, ...	1871.	1
NEUNDORF, . . .	Rhine Valley, near Coblentz,	1869 + 2.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
NEUENKIRCHEN, . .	Lower Austria, . . .	1876.	1
NUENWEG, . . .	Baden, ...	1876 N.–S.	1
NEUFCHATEAU, . .	Vosges, ...	1784.	1
NEUFCHATEAU, . .	Belgium, ...	1878.	1
NEUCHATEL LAKE, .	. . . . .	1856; 1877.	2
NEUCHATEL, Canton of,	. . . . .	1642 + 2; 1648 + 3; 1652; 1670; 1720; 1755; 1842 + 1; 1877; 1879.	15
NEUCHATEL, . . .	. . . . .	1062; 1357; 1523; 1533; 1593; 1619; 1621 + 3; 1650; 1656; 1660 + 5; 1661; 1665 + 4; 1680 + 3; 1681; 1682; 1689 + 3; 1716; 1717; 1749; 1755, very violent; 1756 + 1; 1777; 1784; 1817; 1831 + 3; 1952 + 3; 1853 + 1; 1854 + 1; 1855 S.W.–N.E. + 10; 1856 + 4; 1870; 1871; 1876 E.–W. + 3; 1877; 1879; 1881 + 5; 1882.	86
NEUFEN, ...	Würtemberg, . . .	1855 + 2.	3
NEU GRADISKA, . .	Sclavonia, ...	1854.	1
NEUHÄUSEL, . . .	Hungary, ...	1615.	1
NEUHEIM, . . .	Hesse, ...	1846 + 1; 1869 + 11.	14
NEUHIBEL, . . .	Poland, ...	1786.	1
NEU ISENBURG, . .	Darmstadt, ...	1869, extended over all the country between the Rhine, the Meuse, and the Neckar.	1
NEUKIRCHEN, . .	Cassel, ...	1846.	1
NEUKIRCHEN, . .	Styria, ...	1870.	1
NEU LENGBACH, . .	Lower Austria, . . .	1875.	1
NEUMAGEN, . . .	Rhenish Prussia, . .	1869 + 1; 1881 S.E.–N.W.	3
NEUMÄRHOF, . . near	Agram, ...	1868; 1869.	2
NEUMARK, . . .	Weimar, ...	1858.	1
NEUMARKT, . . .	Carinthia, ...	1875 + 2.	3
NEUMARKT, . . .	Pilsen Circle, Bohemia, .	1858 N.W.–S.E.	1
NEUMARKT, . . .	Upper Styria, . . .	1877 + 2; 1878.	4
NEUMÜHL, . . .	Rhine Valley, . . .	1825 + 2.	3
NEUNKIRCHEN, . .	Sieg C., Rhenish Prussia, .	1869.	1
NEUPAKA, . . near	Gitschen, Bohemia, . .	1861.	1
NEU REICHENAU, . .	Bohemia, ...	1877.	1
NEUSALTZ, . . .	Silesia, Prussia, . . .	1858.	1
NEUSOHL, . . .	Hungary, ...	1752; 1829; 1862 + 1 N.–S.; 1869 N.–S.	5
NEUSS, ...	Dusseldorf, ...	1878.	1
NEUSSEN, . . .	Rhine Valley, . . .	1868.	1
NEUSTADT, . . .	8 miles from Vienna, Austria,	1668; 1712; 1718 + 3; 1768; 1769; 1774 N.W.–S.E. + 2; 1783; 1802; 1829 + 1; 1841; 1858; 1868 S.–W. + 1 N.–S.; 1874 S.W.–N.E.	20
NEUSTADT, . . .	Thuringerwald, Bavaria, .	1831; 1852; 1869; 1881.	4

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
NEUSTADT auf Haardt, ...		1869 + 3 + 1 W.–E. + 1 E.–W. + 3 N.–S.	9
NEUSTADT, . . .	Neuwied C., Rh. Prussia, .	1869 + 1 + 4 N.E.–S.W.	3
NEUTRA COM., . .	Hungary, ...	1838 ; 1855 + 1 ; 1874.	4
NEUTRA ISLAND, . .	Grecian Archipelago, . .	1771.	1
NEU VERBAOZ, . .	Servia, ...	1869.	1
NEUVEVILLE, . .	Neuchatel Canton, . .	1777 ; 1873.	2
NEUWIED, . . .	Rhenish Prussia, . .	1807 S.W.–N.W. + 2 ; 1830 ; 1842 ; 1856 ; 1869 W.–E. + 4.	11
NEVESINJE, . . .	Bosnia, ...	1880 ; 1882 W.–E.	2
NEW CASTILE, . .	. . . . .	1768 ; 1780 ; 1871.	3
NEW CORINTH, . .	Greece, ...	1861.	1
NEWHAM, . . .	Penzance, ...	1850.	1
NEWPORT, . . .	. . . . .	1839 ; 1860 ; 1865 ; 1868.	4
NICASTRO, . . .	Calabria, ...	1609 ; 1826 + 1 ; 1855 + 1 ; 1856 + 2 ; 1858 + 1. 1860 ; 1869.	12
NICE, ...	. . . . .	1564 ; 1565 ; 1612 ; 1644 ; 1664 ; 1767 ; 1771 E.–W. ; 1799 + 1 ; 1806 ; 1807, radius of 6 leagues ; 1808 N.E.–S.W. + 4 ; 1818 ; 1851 ; 1852 W.–E. + 1 ; 1854 S.E.–N.W. + 2 ; 1855 + 13 + 1 S.E.–N.W. + 1 N.–S. ; 1856 + 1 ; 1857 ; 1858 ; 1859 + 12 ; 1860, corresponded with one at Rhodes, + 69, mostly vibrations ; 1861 + 61, mostly vibration ; 1862 + 42, vibrations ; 1866 + 2 E.–W. + 113, mostly vibrations ; 1867 + 113, vibrations ; 1868 + 128, vibrations ; 1869 + 134, vibrations ; 1870 + 283, vibrations ; 1871 + 1 ; 1875 + 1 ; 1876 N.E.–S.W. + 1 ; 1880 + 1.	1017
NICHINO CASALE, near	Aversa, Naples, . . .	1665.	1
NICŒA, ...	. . . . .	362 ; 366 ; 368 ; 372 ; 985 ; 1664 W., repeated frequently during 2 years + 6.	12
NICOMEDIA, . . .	Bythyniæ, ...	127 ; 359 ; 362.	3
NICOLOSI Village, . .	Etna, ...	1633 ; 1842 + 1.	3
NICOPOLIS, . . .	Pontus, ...	127.	1
NICOSIA, ...	Sicily, ...	1822 + 1 ; 1853.	3
NICOTERA, . . .	Calabria, ...	1869.	1
NIDEAUX, . . .	Berne, ...	1882 W.–E.	1
NIEDER BEERBACH, .	Hesse Darmstadt, . .	1825 + 3 ; 1873 + 9 + 1 S.–N.	15
NIEDER BREISIG, . .	Ahrweiler C., Rh. Prussia, .	(1869 + 2) E.–W. + 1.	4
NIEDER BRONN, . .	Bas Rhin, ...	1846.	1
NIEDER DOLLENDORF,	Rhine Valley, . . .	1869.	1
NIEDER ERLENBACH, .	Würtemberg, . . .	1869.	1
NIEDER FLŒRSHEIM, .	Rhenish Hesse, . . .	1869 + 3.	4
NIEDER HEIMBACH, .	Neuwied C., Rh. Prussia, .	1869 + 2.	3
NIEDER MOHR, . .	Nassau, ...	1869 S.W.–N.E.	1
NIEDER MOOS, . .	Rhine Valley, . . .	1869 + 2.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
NIEDERMURATH, . .	Neumburg Prov., Bavaria, .	1862.	1
NIEDERNDORF, . .	Pusterthal, Tyrol, . .	(1862 + 6) S.W.–N.E.	7
NIEDER OLIN, . .	Darmstadt, ...	1869.	1
NIEDER RAD, . .	Frankfurt, ...	1869 + 1.	2
NIEDER RAMSTADT, .	Darmstadt, ...	1873 S.W.–N.E. + 3.	4
NIEDER-RHEIN, . .	. . . . .	*See* Rhine, Lower.	
NIEDERSTADTFELD,	between Moselle and Ahr rivers, .	1869.	1
NIEDERSTOLTZINGEN, .	Würtemberg, . . .	1861.	1
NIEDER WAMBACH, .	Neuwied C., Rh. Prussia, .	(1869 + 1) S.–N.	2
NIEDER WALMENACH, .	Rheingau C., . . .	1869 W.–E.	1
NIEDER WURTZBACH, .	Rhenish Bavaria, . . .	1869 + 1.	2
NIEMEROW, . . .	Podolia, ...	1790.	1
NIERSTEIN, . . .	Rhine Valley, . . .	1869 + 6.	7
NIEVENHEIM, . .	Neuss C., Rhenish Prussia, .	1869.	1
NIGNI-ILDENSK, . .	Asiatic Russia, ...	1864 + 2.	3
NIJNI-TAGILSK, . .	Eastern Ural, . . .	1841 W.S.E.–E.N.E.	1
NICOLAJEW, . . .	Podolia, Russia, . . .	1821 + 2; 1829.	4
NICOLAJEWSKAIA, .	Eastern Shore Black Sea, [Circassia,	1841; 1848 + 2; 1853 + 4.	9
NIMEGUEN, . . .	Holland, ...	1755; 1844; 1845.	3
NISMES, ...	Gard, ...	1763 W.–E.; 1808; 1809; 1836; 1854; 1855 + 1 1862 S.E.–N.W.; 1863; 1873.	10
NIO ISLAND, . . .	Thyra, Greece, . . .	1855.	1
NIORT, ...	Deux Sèvres, . . .	1803; 1834; 1835; 1866.	4
NIPPES, ...	. . . . .	1878.	1
NISI, ...	Greece, ...	1846 + 1.	2
NISYRO ISLAND, . .	Sporades, ...	1862 + 6; *1864*; *1869*; 1871; 1873.	11
NOCERA, ...	Umbria, ...	1719; 1751 + 3; 1752 + 2, simultaneously in the Marches of Umbria; 1804 + 3; 1853.	13
NOCHERN, ...	Rheingau Canton, . .	1869 + 1.	2
NŒFELS, ...	Glarus Canton, . . .	1705 + 1; 1871.	3
NOGENT SUR VERNISSON, .	Loiret, ...	1841 N.–S.	1
NOHAUT, . . . near	La Chartre, Indre, . .	1857.	1
NOILAS (NAILA), . .	Bavarian Palatinate, . .	1786.	1
NOIRETABLE, CANTON, .	Forez, Loire, . . .	1877.	1
NOIRMOUTIER, . .	Vendée, ...	1832; 1833 + 1.	3
NOLA, ...	Terra di Lavoro, . . .	1694; 1853 + 1.	3
NOLAY, ...	Côte d'Or, ...	1871 + 1 S.–N.	2
NONCOURT, . . .	Vosges, ...	1784.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
NONEMVASIA, . .	Peloponnesus, . . .	1858 + 3.	4
NORCIA, ...	Spoleto, ...	1328, completely ruined — 5000 persons perished; 1600 + 2; 1702; 1703 + 1; 1719; 1730 + 6; 1747; 1785 + 6; *1859*, extended to Rome, to Camerino and Pesaro, the town covered with ruins, + 2 N.E.–S.W. + 5; 1860 + 1; 1880; 1881 N.E.–S.W.	35
NORDBY, ...	Aas Parish, Norway, . .	1875.	1
NORDENSTADT, . near	Darmstadt, ...	1785.	1
NORDHAUSEN, . .	Saxony, Prussia, . . .	1785.	1
NORDLINGEN, . .	Bavaria, ...	1510; 1517, 2 miles radius; 1869.	3
NORDSESSYL, . . .	Iceland, ...	1755 + 1.	2
NORF, ...	Neuss C., Rhenish Prussia, .	1869.	1
NORFOLK, County, . .	. . . . .	1165; 1201, 1869.	3
NORMANDY, . . .	. . . . .	1214; 1588; 1691; 1755, violent; 1829; 1853 N.N.W.–S.S.E.; 1878 S.–N.	7
NORRDELGE, . .	East of Upsala, Sweden, .	1822; 1823 + 1.	3
NORTES, ...	Hautes Pyrénées, . .	1775.	1
NORTHAMPTON, . .	. . . . .	1750; 1776.	2
NORTHAMPTONSHIRE, .	. . . . .	1731; 1750.	2
NORTHERN SEA, . .	. . . . .	1858, three immense waves advanced from the W.S.W., with shock.	1
NORWAY, ...	. . . . .	1623, very violent; 1755, 1784; 1791; 1810; 1811; 1819; 1834; 1842; 1853; 1866.	11
NORWAY, Southern, .	. . . . .	*1657*, extended from Œsterdal to Bohus in a N.–S. direction 40 Norwegian miles, and from the Swedish Frontier to Lindesnäs, E.–W., + 1.	2
NORWAY, West of, . .	. . . . .	1786.	1
NORWICH, . . .	. . . . .	1795.	1
NOTO, ...	Sicily, ...	1693; 1727; 1846; 1848.	4
NOTTINGHAM, . .	. . . . .	1110; 1792; 1816; 1865; 1868; 1873.	6
NOTTINGHAMSHIRE, .	. . . . .	1750.	1
NOUKA or NUCKA, . .	Lat. 41° 12′ Long. 44° 52′ Caspian Sea,	1854; 1861 + 1; 1866 S.E.–N.W. + 3.	7
NOVARA, ...	Piedmont, ...	1850; 1851; 1854.	3
NOVELDA, . .	Alicante Province, . .	(1854 + 1) S.W.–N.E.	2
NOVELLARA, . . .	. . . . .	1805.	1
NOVOKRACINA, . near	Klana, Illyria, . . .	1870.	1
NOVOSSELSTEY, . .	Besserabia, ...	1868 + 2.	3
NOVI, ...	Italy, ...	1828 + 1.	2
NUFENEN, . . .	Switzerland, . . .	1880 + 1.	1
NUITS, . . . , .	Côte d'Or, ...	1882.	1
NUNKEL, ...	Rhine Valley, . . .	1869.	1
NUREMBERG, . . .	. . . . .	1670; 1769; 1812 + 3; 1847.	7

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
NURSIA, ...	. . . . .	B.C. 103.	1
NYEK, ...	Hungary, ...	1870.	1
NYEREGYHAZA, . .	,, ...	1868 + 3.	4
NYON, ...	Vaud Canton, . . .	1879.	1
OBAN, ...	Argyleshire, . . .	1841 + 1; 1880.	3
OBDACH, ...	Styria, ...	1881.	1
OBEDAS, ...	Portugal, ...	1756.	1
OBENDORF, . . .	Würtemberg, . . .	1871 + 1.	2
OBERBEERBACH, . .	Odenwald, Hesse Darmstadt,	1869 + 2.	3
OBERCASSEL, . . near	Bonn, ...	1795; 1856; 1869.	3
OBERDORF, . . .	Bavaria, ...	(1882 + 3) W.–E.	4
OBERDRAUBURG, . .	Carinthia, ...	1881 N.W.–S.E.	1
OBER DOLLENDORF, .	Rhine Valley, . . .	1869.	1
OBERHALBSTEIN, . .	Grisons, ...	1812 + 1.	2
OBERKLINGIN, . .	Odenwald, . . .	1869; 1873.	2
OBERKIRCH, . . .	Switzerland, . . .	1882.	1
OBERLAND, . . .	Bernese, ...	1839 + 1; 1851; 1861.	3
OBERLAHNSTEIN, . .	Nassau, ...	1869 + 2 + 1 E.–W.	4
OBERMAIS, . . near	Meran, Tyrol, . . .	1873 + 3.	4
OBERMARKSTHAL, .	Würtemberg, . . .	(1830 + 2) W.–E.	3
OBERBREIT, . . .	Bavaria, ...	1877.	1
OBERNBURG, . . .	Styria, ...	1867.	1
OBERNDORF, . . .	Würtemberg, . . .	(1837 + 1) E.–W.; (1855 + 2) N.–S.	5
OBERNEUKIRCHEN, .	Upper Austria, . . .	1867; 1868.	2
OBERPFALZ, . . .	Bavaria, ...	1860.	1
OBERPOLAIN, . . .	Isergebirge, Bohemia, . .	1877.	1
OBER RAMSTADT, . .	Odenwald, Darmstadt, . .	1875.	1
OBERSTOCK, . . .	Rhine Valley, . . .	1869.	1
OBERTURKHEIM, . .	Würtemberg, . . .	1861.	1
OBERUSTER, . . .	Zurich Canton, . . .	1851.	1
OBERVILLACH, . .	Carinthia, ...	1855; 1860 N.W.–S.E.; 1862 S.W.–N.E.; 1881 N.W.–S.E.	4
OBERWALD, . . .	Valais, ...	1855 W.–E.	1
OBERWESEL, . . .	St. Goar C., Rh. Prussia, .	1619; 1845; (1869 + 1) S.E.–N.W. + 2 S.W.–N.E. + 2 E.–W.	8

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
OBERWIESENTHAL, .	Saxon Voigtland, . .	1862 N.W.–S.E.	1
OBERWINTER, . .	. . . . .	1869 S.–N.	1
OBERZIERUNG, . .	Styria, ...	(1861 + 2) N.–S.	3
OBROVAZZA, . . .	Austria, Mediterranean, .	1843 ; 1850 S.W.–N.E. + 2.	4
OCCHIEPPO, . . .	Piedmont, ...	1881.	1
OCHIL HILLS, . .	. . . . .	1734.	1
OCSA, ...	Schüt Island, Danube, .	1877 + 1.	2
ODENKIRCHEN, . .	Rhenish Prussia, . .	1869.	1
ODENSEE, . . .	Denmark, ...	1824.	1
ODENWALD, . . .	Darmstadt, ...	1790 ; 1846 ; 1855 ; 1869 + 1 ; 1871 + 2 ; 1872 + 2 ; 1873 S.W.–N.E., extended to Manheim across Rhine Valley, + 39 ; 1874 + 8 ; 1876 ; 1877 + 1 ; 1878.	64
ODENBURG, . . near	Gratz, ...	1863 ; 1867.	2
ODESSA, ...	. . . . .	1821 ; (1829 + 4) N.–S., observed by Hauy ; 1831 + 5 ; 1838 + 2 N.W.–S.W. ; 1843 N.–S. ; 1844 ; 1854 + 1 ; 1868 + 3 ; 1869 + 1 ; 1880 S.S.W.–N.N.E. + 1.	27
ODENBURG, . . .	Hungary, ...	1783 ; 1813 + 1 ; 1876.	4
ODIVILLAS, . . .	2 leagues from Lisbon, .	1756.	1
ŒDELSBURG, . . .	Carinthia, ...	1834 N.–S. + 1.	2
ŒDERAU, N.N. of, .	Saxony, ...	1879.	1
OESTRICH, . . .	Nassau, ...	1869 + 1 E.–W.	2
OELLINGEN, . between	Rhine and Sieg, . . .	1869.	1
OELSNITZ, . . .	Saxon Voigtland, . .	1875.	1
ŒREBRO, . . .	Gothland, Sweden, . .	1759 S.E.–N.W. + 3 ; 1847 ; 1879 S.E.–N.W.	6
ŒSTERDAL, . . .	Norway, ...	1834.	1
OEX CHATEAU, . .	Vaud Canton, . . .	1861 ; 1878 + 1.	3
OFEN, ...	Hungary, ...	1578 : 1786 ; 1788 + 3 ; 1814 + 6 ; 1826 ; 1868 ; 1870.	16
OFFENBACH, . . .	Darmstadt, ...	1728 ; 1733 ; 1869 + 4 ; 1878.	8
OFFENBURG, . . .	Baden, ...	1825 + 2.	3
OFFENERGEBIRGE, .	Hungary, ...	1880.	1
OFFEUX, . . .	St. Blemont, Somme, . .	1882 + 2.	3
OGENNE, ...	Navarreux C., B. Pyrénées,	1784 ; 1802 ; 1817.	3
OGGERSHEIM, . .	Bavaria, ...	1789.	1
OIGNON VALLEY, . .	Eastern France, . . .	1881.	1
OGULIN, ...	Croatia, ...	1876.	1
OGUS FORT, . . .	Narentu Valley, Dalmatia, .	1882 W.–E.	1
O'GYALLA, . . .	Hungary, ...	1875 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
OHMENHAUSEN, . near	Reutlingen, Würtemberg, .	1875 + 1.	2
OHNASTTETIN, . .	Swabia, ...	1828 + 1.	2
OISANS, ...	Iserè, ...	(1839 + 3) N.E.–S.W.	4
OISSEL, ...	Seine Inférieure, . . .	1848 S.W.–N.E. ; 1850.	2
OJIJARES, . . near	Granada, ...	1863.	1
OJTOOZ, ...	Transylvania, . . .	1862 + 1.	2
OKIC, . . . near	Rakovpatok, Croatia, . .	1881 + 1.	2
OKOLICSNA, . . .	Hungary, ...	(1786 + 2) W.–E.	3
OLARSVIK, . . .	Iceland, ...	1784 + 2.	3
OLDHAM, . . .	. . . . .	1869.	1
OLERON ISLAND, . .	Charente Inférieure, . .	1776 + 6 ; (1799 + 1) S.W.–N.E. ; 1805 + 1 ; 1814.	12
OLERON, ...	Basses Pyrénées, . . .	1782 + 1 ; 1784 ; 1817 ; 1847 + 1 ; 1853 E.–W. 1864 (shocks occur 2 or 3 times in the year) ; 1867 ; 1874 W.–E.	10
OLETTE, ...	Pyrénées Orientales, . .	1819.	1
OLGOPOL, . . .	Podolia, ...	1821 + 2.	3
OLIVONE, . . .	Ticino Canton, Switzerland,	1882.	1
OLIVENZA, . . .	Portugal, ...	1857.	1
OLLON, ...	Vaud Canton, . . .	1874 N.W.–S.E. ; 1881.	2
OLMUTZ, ...	Moravia, ...	1858 ; 1863.	2
OLOT, ...	Cataluña, ...	1427 ; 1852 + 1 W.–E. ; 1853.	4
OLTON, ...	Solothurn Canton, . .	1846 ; 1855 ; 1861 E.–W. ; 1881.	4
OLVES BIGDEN, . in	Aarness Syssel, Iceland, .	1706 ; 1749, very violent.	2
OLYMPUS MOUNTAIN, .	. . . . .	1860 ; 1862.	2
OMAGH, ...	. . . . .	1880.	1
OMBLA, ...	Guippana Island, Adriatic, .	1843 + 10.	11
OMBRIA, ...	. . . . .	1849 + 3, many shocks ; 1854 + 8 ; 1871.	14
ONEGLIA, . . .	Piedmont, ...	1854 ; (1858 + 1) N.–S. ; 1871 E.–W.	4
ONI-KUTAIS, . . .	Transcaucasia, . . .	1851 + 1.	2
ONSTMETTINGEN, . .	Prussia, ...	(1830 + 2) W.–E. + 1.	4
ONTAK, ...	Asia Minor, . . .	1869 + 2, town swallowed up as in a whirlpool.	3
OPLADEN, . . .	Solingen C., Rh. Prussia, .	1869.	1
OPORTO, ...	. . . . .	*1755*, destructive ; 1761, very violent ; 1807 ; 1830 ; 1841 ; 1857 + 1 ; 1858 + 1 ; 1863 ; 1867 ; 1868.	12
OPPENHEIM, . . .	Hesse Cassel, . . .	1845 ; 1848 ; 1858 ; 1869 + 8.	12
OPPIDO, ...	Calabria, ...	1852 ; 1869.	2
OPUS, ...	Greece, ...	A.D. 306.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ORUS FORT, . . .	Adriatic, ...	*1834* + 6; 1843; 1851 + 8, as at Stagno Picole.	17
ORAN, ...	Algeria, ...	1755; 1790 + 24; 1791; 1819 + 3; 1836 + 1; 1849; 1854 + 2; 1857 + 1; 1858 + 1; 1859 + 5; 1860 + 1; (1861 + 3) W.–E. + 1 S.–N. + 2; 1864 S.E.–N.W. + 1; 1865 + 1; 1867; 1871 + 3; 1872; (1873 + 1) E.–W.	68
ORANGE, ...	Vaucluse, ...	1855.	1
ORAVICZA, . . .	Istria, ...	(1871 + 1) S.E.–N.W.	2
ORBAYCETA, . . .	Navarra, Spain, . . .	1853.	1
ORBANO, ...	Piedmont, ...	1878 E.–W. + 1.	2
ORBE, ...	Vaud Canton, . . .	1601; 1680 + 3; 1692; 1846 S.–N. + 2 + 1 N.–S.; 1876 + 1.	12
ORBEC, ...	Calvados, ...	1847 W.–E.	1
ORCHOMENOS, . .	Greece, ...	B.C. 426.	1
ORCIANO, . . .	Pisa, ...	1846, very violent, + 2 + 1, very violent, + 71; 1848 + 1.	77
ORCINOVI, . . .	North Italy, . . .	1802.	1
ORCIVAL, . . .	Puy de Dôme, . . .	1863 + 2.	3
ORDUÑA, . . .	Biscay, ...	1847 E.–W.	1
OREILLE, . . .	Savoy, ...	(1818 + 1) N.W.–S.E.	2
ORGAZ, ...	Toledo District, . . .	1755 + 3 + 2.	6
ORGELET, . . .	Jura, ...	1781.	1
ORGIVA, ...	Andalucia, ...	1863.	1
ORGON, ...	Bouches du Rhone, . .	1806 + 1; 1863 S.–N.	3
ORIHUELA, . . .	Valentia, ...	1748; 1821 + 26 (shocks lasted 26 days); 1823 + 200; 1829 + 4; 1833 + 2; 1844 + 1; (1854 + 1) S.W.–N.E.; (1858 + 2) N.–S., extended along the whole coast; 1859; 1867.	246
ORIOVACS, . . .	Croatia, ...	1858 + 3; (1859 + 2) S.W.–N.E.	7
ORLÉANS, . . .	. . . . .	1579; 1682; 1755; 1831 + 3; 1841.	8
ORLEANSVILLE, . .	Algeria, ...	1853; 1866; 1867 + 1 E.–W.	4
ORMES, ...	Vienne, ...	1846.	1
ORMONTZ, . . .	Vaud Canton, . . .	1874 N.W.–S.E.	1
ORMSKIRK, . . .	. . . . .	1871.	1
ORNANS, ...	Doubs, ...	1873.	1
ORNAVASSO, . . .	Palanza, Piedmont, . .	1881; 1882 + 2.	4
OROPA MOUNTAINS, .	Lombardy, ...	1807.	1
OROPO, ...	Greece, ...	1860.	1
ORPIRI, ...	Kutais, Russia, . . .	1852.	1
ORSA, ...	Syria, ...	1872.	1
ORSAY, ...	Seine, ...	1841 S.–N. + 6.	7

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ORSOGNA,	Abruzzi,	1881, violent, + 1 N.W.–S.E. + 1 ; 1882 + 2.	6
ORSOMARSO,	Calabria Citra,	1825 + 1.	2
ORSOVA,	Bannat, Hungary,	1838 + 1 ; 1864 + 3 ; (1879 + 1) E.–W. ; 1881.	9
ORTENBERG, near	Offenburg, Hesse Darmstadt,	1880 ; (1881 + 3) E.–W..	5
ORTHEZ VALLEY,	Basses Pyrénées,	1818 ; 1858 ; 1865 ; 1873 W.N.W.–E.S.E.	4
ORTONA,	Abruzzi Citra,	1782 ; 1881.	2
ORVIETTO,	. . . . .	1349 ; 1695 ; 1756 ; 1802 + 2.	8
OSANN,	Rhine Valley,	1869.	1
OSBORNE,	England,	1878.	1
OSIMO,	Ancona District,	1870.	1
OSNABRUCK,	Hanover,	1767 ; 1878.	2
OSSAU VALLEY,	Basses Pyrénées,	1773 ; (1779 + 1) S.W.–N.E. ; 1800 + 1.	5
OSSIACH,	Carinthia,	1857 + 1 W.–E.	2
OSTABAT,	Basses Pyrénées,	1858.	1
OSTENDE,	. . . . .	1848.	1
OSTERACH,	Würtemberg,	1878.	1
OSTERBURG,	Saxony, Prussia,	1879 S.–N.	1
OSTRAU,	Poland,	1786.	1
OSURGELY,	Caucasus,	(1870 + 1) W.–E.	2
OTCHAKOW,	Kherson, S. Russia,	1790 ; 1821 + 2 ; 1829.	5
OTRANTO PROVINCE,	. . . . .	1395 ; 1743 ; 1826 + 3 ; 1851.	7
OTRANTO,	. . . . .	1810.	1
OTTOJANO, near	Vesuvius,	1754.	1
OTTENBACH,	Zurich, Canton,	1861.	1
OTTOCAC, near	Zeng, Dalmatia,	1852 S.–N. ; 1869 ; 1870 + 3 ; 1880 W.–E.	7
OTTWEILER,	Rhenish Prussia,	1878.	1
OUCHAK,	2° long. E. of Smyrna,	1866 + 2.	3
OUCHES,	Savoie, Chamouni Valley,	1817 + 24 + 1 S.W.–N.E. + *1* S.–N.	27
OUCQUES,	Loire et Cher,	1864.	1
OUED-DJER,	Algeria,	1867, the springs on the slopes of the lesser atlas dried up, + 3.	4
OUED-MAMMORA,	9 leagues W. of Aumale, [Algeria,	1864 + 1.	2
OUED-SAHEL,	Algeria,	1860.	1
OUENOUPHA,	Algeria,	(1885 + 1) N.W.–S.E., great fissures formed, one N.W.–S.E. + 2 ; 1854.	5
OUGES,	5 km. S.E. Dijon, Côte d'Or,	1866.	1
OULED-RHAMOUN,	Constantine Prov., Algeria,	1862.	1
OULENS,	Vaud Canton,	1846.	1
OULLINS,	S. of Lyons,	1857.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
OUMAKAN JOUST,	Lat. 43° 22′, Long. 43° 40′, } Caucausus,	1853 + 1.	2
OURMOURBEG,	Anatolia,	1863 + 1.	2
OUST KAMMSGORSK,	Russia,	1867.	1
OVERRATH,	Mulheim C., Rh. Prussia,	1869.	1
OVSIANSKAIA,	Jennessi Gov., Russia,	1849.	1
OXENHALL,		1179.	1
OXFORD,		1666; 1683; 1764.	3
OXFORDSHIRE,		1812.	1
OYAZZUN,	Vascongadas, Spain,	1854 N.–S.	1
OZYRAT,	Portugal,	1756 + 3.	4
PAASDORF,	Austria,	1865.	1
PACALIERI,	Piedmont,	1808.	1
PADERBORN,	Westphalia, Prussia,	1767.	1
PADUA,		1268; 1365; **1487**; 1511; 1693; 1719 + 3; 1725; 1737 + 3; 1741; 1743; 1747; 1754; 1755; 1756 + 6; 1766; 1768; 1769 + 2; 1771; 1772 + 2; 1774 + 3; 1775 + 3; 1776; 1777; 1778 + 1; 1779 + 5; 1780 + 4; 1781 + 7; 1783 S.–N. + 1; 1785 + 3; 1786 + 1; 1787 + 4; 1789; 1834; 1857 + 1 + 2 N.E.–S.W.; 1859 E.–W.; 1861; 1869 + 1; 1880; 1881.	91
PADULA,	Principato Citra,	1857.	1
PAESANA,	Piedmont,	1808 + 1.	2
PAGNO,	,,	1808.	1
PAGERBACH,	Lower Austria,	1879.	1
PAIA,	Portugal,	1841.	1
PAINBŒUF,	Loire Inférieure,	1855.	1
PAISSAIS,	Orne,	1867.	1
PAKRACZ,	Porega Comt., Hungary,	1859 + 2.	3
PALANZA,	Como,	1881; 1882.	2
PALATINATE,		1623 + 3; 1624; 1786.	6
PALATINATE, Hessian,		1871.	1
PALAZZO-ADRIANO,	Palermo, Sicily,	1876.	1
PALAZZUOLO,	Romagna,	1879 + 3; 1880, extended to Florence, + 1; 1881 + 5.	12
PALBOROUGH,		1834.	1
PALENCIA,	Spain,	1817.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
PALENZA Valley, . .	Switzerland, . . .	1512.	1
PALERMO, . . .	. . . . .	1686, 40 miles radius; 1726, very violent, + 3; 1726 + 9, felt at Malta; 1736; 1740; 1751; 1783 + 3; 1792; 1794 + 2; 1797; 1799; 1800; 1801; 1803 + 3 + 2 E.–W.; 1804; 1817; 1818; 1819 + 3; (1823 + 5) N.E.–S.W. + 4; 1824; 1826 + 1; (1827 + 6) W.–E. + 5; 1828 + 1; 1831 + 2 + 2; 1835 + 3 N.E.–S.W.; 1838; 1839 + 1; 1843 E.–W. + 6; 1845 E.–W. + 4 N.E.–S.W. + 2 + 6 E.N.E.–W.S.W.; (1846 + 2) N.E.–S.W. + 1 S.S.E.–N.N.W.; 1847 N.–S. + 1 E.–W. + 1 S.W.–N.E. + 1; 1848 E.N.E.–W.S.W. + 1; 1852 N.–S.; 1856 N.E.–S.W. + 2 E.–W. + 1 S.E.–N.W.; 1857 N.E.–S.W.; 1864; 1868; 1870 E.–W. + 5 + 1 N.–S.; (1871 + 1) E.–W. + 16 W.–E.	145
PALESTINE, . . .	. . . . .	B.C. 33–32; A.D. 33; 419; 550; 631 + 30, (lasted 30 days); 658; 746; 1032; 1201; 1546.	40
PALESTRINA, . . .	Rome, ...	1844 + 44.	45
PALICE Valley, . .	Piedmont, ...	1808 + 2.	3
PALMA, ...	Majorica Island, . . .	1835 + 2; 1851 + 2; 1852 + 3; 1863 + 3 1864.	15
PALMA NOVA, . . .	Venetia, ...	1876.	1
PALMI, ...	Reggio Province, Calabria, .	1858 + 3; 1863 + 1.	6
PALOMBURO, . . .	Etna, ...	1880.	1
PALVALVA, . . .	Hungary, ...	1867 N.–S.	1
PAMARANCHE, . .	Tuscany, ...	1853.	1
PAMPELUNA, . . .	. . . . .	1817.	1
PANERNO, . . .	Marmora Coast, . . .	1858 + 1; 1859 + 3.	6
PANKRATZ, . . .	Bohemia, ...	1856 + 1.	2
PANNESCHEIDE, . near	Aix-la-Chapelle, . . .	1874 N.E.–S.W. + 2.	3
PANTELANDOLES, . .	Molise Province, . . .	1853.	1
PANTELLARIA ISLAND,	Sicily, ...	(1816 + 1) S.W.–N.E., in the line of the volcanoes of the region.	2
PAOLA, ...	Calabria, ...	1846; 1854; 1862; 1863 + 1; 1868; 1870 + 1; 1881 N.–S. + 1.	10
PAPASIDERO, . . .	Basilicata, ...	1825.	1
PAPHLAGONIA, . .	. . . . .	967.	1
PAPHOS = BAFFA, . .	Cyprus, ...	1144.	1
PAPPENHEIM, . .	Bavaria, ...	1787.	1
PARAME, . . . near	St. Malo, Ille et Vilaine, .	1871.	1
PARDINES, . . .	Auvergne, ...	1733 + 3.	4
PARIS, ...	. . . . .	1580; 1682; 1692; 1711, 30 leagues radius; 1756 + 1; 1760 + 1; 1769; 1783 + 3; 1799; 1822; (1841 + 2) N.E.–S.W.; 1855; 1857; 1878.	21

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
PARMA, ...	. . . . .	1104; 1293; 1438; 1481 + 2; 1767 + 1; 1768; (1774 + 5) S.–N.; 1775 + 3; (1802 + 2) W.–E.; 1810; 1818 + 1; 1819; (1831 + 3) N.E.–S.W. + 6; (1832 + 7) N'.–S'. + 15; 1833 + 1 S.E.–N.W.; 1834 S.E.–N.W. + 4 N.W.–S.E. + 3 + 2 S.W.–N.E, simultaneously at Bologna, Padua, Venice; 1836 E.–W. + 3 E.–W. + 1; (1840 + 2) S.E.–N.W., and at Lucca; 1841 E.–W. + 1 S.E.–N.W.; (1843 + 1) E.N.E.–W.S.W.; 1844 + 4; (1845 + 1) S.E.–N.W. + 1 N.E.–S.W. + 1; (1847 + 1) S.E.–N.W. + 1; 1849 + 1 S.–N.; 1850; 1851; 1852 W.–E.; 1854 N.W.–S.E. + 1; (1855 + 1) S.S.W.–N.N.E. + 1 N.–S. + 1 E.–W.; 1856 N.–S. + 1 E.–W. + 3; 1857 E.S.E.–W.N.W. + 1; 1858 S.W.–N.E.; 1864 + 1; 1869 + 1 E.S.E.–W.N.W. + 1; 1870 + 1; 1874 + 3; 1882.	126
PARNASSUS MOUNTAIN,	Greece, ...	1860 + 1; 1870 + 6; 1879.	10
PAROPOHÉ, . . .	Croatia, ...	1871.	1
PAROS ISLAND, . .	. . . . .	1508; 1837.	2
PARRET Valley, . .	Somerset, ...	1868.	1
PARSANA, . . .	Piedmont, ...	1878 + 1 E.–W.	2
PARTENHEIM, . .	Darmstadt, ...	1869.	1
PARTENKIRCHEN, . .	Bavaria, ...	1864; 1880 N.–S.	2
PARTHENAY, . . .	Deux Sèvres, . . .	1772 + 2; (1836 + 2) N.W.–S.E.	6
PARTHENAY-le-Peuple,	. . . . .	1798.	1
PASIANO, ...	Padua, ...	1861.	1
PASITANO, . . .	Coast of Amalfi, . . .	1687.	1
PASLA, Commune, . .	Calabria Citra, . . .	1842.	1
PASSANAUR, . . .	Gudomakar, Caucasus, . .	1868 + 5.	6
PASSAU, ...	Bavaria, ...	1858; 1876.	2
PASSINA, ...	Pisa, ...	1852.	1
PASSY, ...	Haute Savoie, . . .	1868.	1
PASTUSIE Valley, . .	Sardinia, ...	1838.	1
PATERNION, . . .	Carinthia, ...	1850 N.–S.; 1881 S.W.–N.E.	2
PATERNO, . . .	Catania, Sicily, . . .	1846; 1865; 1866.	3
PATERNO, . . .	Calabria Citra, . . .	1854; 1855; *1857 + 5.*	8
PATRAS, ...	. . . . .	1714 + 1; *1785*; 1804 + 1; 1817 + 8; 1829 + 6; 1842 + 3; 1844; 1846 + 3; 1847 + 1; 1853 + 3; 1861; (1866 + 2) E.–W. + 1 E.N.E.–S.W.S. + 2; 1867 + 26; 1876.	71
PATTI, ...	Sicily, ...	1786; 1842 + 6; 1845.	9
PATTINO MOUNTAIN, .	N.E. of Norcia, . . .	1859, extended to Rome, Camerino, and Pesaro.	1
PAU, ...	. . . . .	1763; 1768; 1773 + 5; 1777, extended to Commingues and the Pays de Foix; 1778; 1807 + 2; 1817; 1818; 1835; 1850 + 1; 1851; 1852 N.–S. + 2; 1854; 1855; 1862; 1863; 1865; 1867; 1868.	29
PAULIN, ...	Moselle Thale, . . .	1869.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
PAVIA,		837; 1473; 1851; 1864.	4
PAWLOWSK,	Woronesch Gov., Russia,	1823 + 3; 1825.	5
PAXO ISLAND,	Ionian Islands, Greece,	1867.	1
PAYERNE,	Vaud Canton,	1817; 1852; 1853 E.–W.; 1881.	4
PAYO,	Spain,	1785 + 3.	4
PAYS DE FOIX,		(1765 + 7) N.–S.; 1777.	9
PÉAGE,	Isère,	1861.	1
PEDARA,	Etna, Sicily,	1869 + 3.	4
PEGO,	Alicante,	1856 + 2.	3
PEGOMAS,	Bouches du Rhône,	1854.	1
PEISSENBERG,	Bavaria,	1787.	1
PELION, Zagora Mountain,	Thessaly,	1882 + 2.	3
PELOPONNESUS,		B. C. 424; 373; A. D. 1820; 1858; 1860 + 2; 1861; 1865.	9
PELURI,	Albania,	1858.	1
PENARO DI MODENA,		1870.	1
PENDLEBURY,	Lancaster,	1864.	1
PENDLETON,		1869.	1
PENEZ,	Pesth Com.,	1863.	1
PENNE,	Abruzzi Citra,	1845.	1
PENNIG,	Upper Saxony,	1821; 1862.	2
PENRITH,		1787.	1
PENSFORD,		1852.	1
PENTEPIGADIA,	Epirus,	1858; 1860 + 3.	5
PENTON,		1818.	1
PENZAGNO,		1877.	1
PENZANCE,		1757; 1843; 1855; 1858; 1859; 1860.	6
PEPERISKA,	Messenia Province, Greece,	1846.	1
PEPERNO,	Terra di Lavoro,	1770.	1
PERA,	Rumili, Turkey,	1802; 1855; 1857 + 1; 1862; 1878.	6
PERAROLO,	Venetia,	1881 + 2.	3
PERESCEN,	Hungary,	1880.	1
PERGAMOS = BERGAMO,	Asia Minor,	1860.	1
PERGINE,	Tyrol,	1881 + 1.	2
PERIGUEUX,		1855.	1
PERITZ,	Saxony,	1880 S.W.–N.E.	1
PERJAMOS,	Servian Woiwod,	(1859 + 2) E.–W.; 1879 + 2.	6
PERM,	Russia,	1798 S.W.–N.E., extended to the Ural mountains over an area of 500 versts × 150 versts.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
PERMANI, . . .	Illyria, ...	1870.	1
PERNAU, . . .	Livonia, Russia, . . .	1670.	1
PERNEGG, . . .	Murzthal, Styria, . .	1865.	1
PERNARANCE, . .	Tuscany, ...	1846 S.S.W.–N.N.E.	1
PERONNE, . . .	Somme, ...	1873 + 1.	2
PEROSA, ...	Piedmont, ...	1808.	1
PERPIGNAN, . . .	. . . . .	1776 + 1; 1797; 1818 + 1; 1824; 1843; 1862 N.E.–S.E.	8
PERRERO, . . .	Pignarolo, ...	1881.	1
PERTH, ...	. . . . .	1597; 1801; 1816; 1824; 1846; 1852;	6
PERTHSHIRE, . .	. . . . .	1834; 1880 + 3.	5
PERTOSA, . . .	Abruzzi Citra, . . .	*1875 + 5.*	6
PERTS, ...	Hungary, ...	1829 + 6.	7
PERUGIA, . . .	Italy, ...	1328; 1457 + 26; 1719; 1753 + 1; 1832; 1837 N.–S.; 1854 + 15; 1861 + 2; 1865 + 7 + 1 N.E.–S.W., + 21; 1867; 1869; 1870 + 1; 1881 + 18; 1882 + 20.	126
PERUGIA PROVINCE, .	. . . . .	1882 + 20.	21
PERZAGNO, . . .	Dalmatia, ...	1880.	1
PESARO, ...	. . . . .	B. C. 101; A.D. 1672; 1826 S.E.–N.W. + 8; 1827; 1828 + 1; 1838 E.–W.; 1842 + 2; 1851; 1853; 1854 + 1; 1859 + 1.	24
PESCARA, . . .	Abruzzi, ...	1881.	1
PESCATINE, . . .	Verona Ter., . . .	1880.	1
PESSEC, ...	Gironde, ...	1852.	1
PESTH, ...	. . . . .	1763 + 1; 1783; 1806; 1813; 1814 + 6; 1826; 1850, violent; 1851; 1865 + 1; 1868 + 13 + 1 E.–W.; 1880.	33
PETERBOROUGH, . .	. . . . .	1813; 1863.	2
PETERCHURCH, . .	Wales, ...	1853.	1
PETERWARDEIN, . .	Croatia, ...	1764.	1
PETERWASAR, . .	Haves Com., Hungary, .	1867 + 6.	7
PETHERTON, S., . .	Somerset, ...	1868.	1
PETIT VILLAGE, . .	Constantine Province, Algeria,	1850; (1867 + 1) W.–E.	3
PETIT HUNINGUE, near	Basle, ...	1840.	1
PETRINA, . . .	Greece, ...	1867.	1
PETRINJA, . . .	Croatia, ...	1876 S.W.–N.E.	1
PETROLI, . . .	Sicily, ...	1818.	1
PETROWSK, . . .	Caucasus, ...	1863, and littoral between Derbent and the mouth of the Terek, + 15; (1869 + 1) S.W.–N.E. + 2 N.–S. 1871 + 4 + 4 E.–W.	29
PETSCHAU, . . .	Bohemia, ...	1862.	1
PETTAU, ...	S. of Marburg, Styria, .	1873; 1877; 1880 + 2.	5

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
PETWORTH,	. . . . .	1834.	1
PEYRENEVE,	Aspe Valley, Pyrénées,	1778.	1
PFALZFELD,	Rhine Valley,	1869 N.–S.	1
PFEDERSHEIM,	Darmstadt,	1869 + 1.	2
PFEFFIKON,	Zurich Canton,	1851 + 1.	2
PFIFFIGHEIM,	Darmstadt,	1869 + 1.	2
PFORZHEIM,	Bavaria,	1871; 1874; 1880.	3
PFRAUENBERG,	Bohemia,	1858.	1
PFUNDS,	Tyrol,	1868.	1
PFUNGSTADT,	Darmstadt,	1869 + 4; 1873 + 6; 1874.	13
PHŒNICIA,	. . . . .	550.	1
PHARMEZI,	Messenia Province, Greece,	1846.	1
PHILIATRA,	Morea,	1867 + 3 + 2 W.–E.	6
PHILIPPSBURG,	Baden,	1880.	1
PHILIPPSEICH,	E. of Frankfurt,	1869 + 5.	6
PHILIPVILLE,	Constantine Province, Algeria,	1856 + 125 (many shocks every day from 22nd August to 2nd October, say 40 days × 3), + 5; 1859; 1861 + 1; 1862 + 3 + 1 N.–S.; 1864; 1866 N.–S.; 1869 W.–E. + 1; 1876.	139
PHILIPPOPOLI,	Rumili,	1750; 1759; 1818; 1855 + 2; 1858; 1859 + 1 + 1 E.–W.; 1861; (1862 + 2) E.–W.; 1863, extended between the Rhodope mountains and the high Balkans, not far from the junction of the two chains, + 2; 1867; 1880 + 1.	20
PHILLIPI,	Macedonia,	A.D. 52.	1
PHLADDA,	Scotland,	1880.	1
PHOCEA,	Asia Minor,	1867 + 5.	6
PHORITZALA,	Messenia Province, Greece,	1846.	1
PHRYGIA,	. . . . .	B.C. 23–22; A.D. 447.	2
PHTHIOTIS Province,	Greece,	*1870* + 4, disastrous.	5
PIACENZA,	. . . . .	1719; 1837 E.N.E.–W.S.W.; 1838; 1882.	4
PIANO DEL VOGLIO,	Appenines,	1870.	1
PIATIGORSK,	Kaisan, Russia,	1852 + 2; 1853; 1855; 1861 S.E.–N.W. 1866; 1869 E.–W.	8
PIAVE,	Treviso Province,	1859 S.S.E.–N.N.W + 10; 1860.	12
PICARDY,	. . . . .	1755.	1
PICCOLO San Bernardo,	. . . . .	1880.	1
PIC DU MIDI, Hotel,	Pyrénées,	1847 + 1; 1876 + 1 E.–W. + 1 N.–S., extended over the whole country between Bagnières de Bigorre and Cape Vern.	5
PICERNO,	Basilicata,	1880.	1
PICKLES,	Bohemia,	1824.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
PIEDMONT,		1248; 1584; **1611**; 1642; 1753; 1755; 1756; 1808, very violent, + 1, centre at Abries; 1831; 1837; 1857; 1881, extended to Genoa.	13
PIEDIMONTE,	Sicily,	1865; 1867; 1870.	3
PIE-DE-MULERA Valley,	Piedmont,	1858.	1
PIENZA,	Sienna, Italy,	1843 + 1; 1849; 1851.	4
PIERREFITTE,	Meuse,	1854.	1
PIERRELATTE,	Drôme,	1773; 1873 N.W.–S.E.	2
PIETRAFITTA,	Calabria Citra,	1854.	1
PIETRA MALA,	Tuscany,	1864 + 3.	4
PIETRA SANTA,	Lucca,	1847.	1
PIEVE,	Umbria,	1753.	1
PIEVE DI CADORE,	Belluno,	1881 + 2.	3
PIEVE DI SOLIGO,	Venetian Territory,	1859.	1
PIEVE SAN LUCE,	Tuscany,	1846.	1
PIEVE SAN STEFANO,	,,	1824; 1856 + 60, extended 100 miles towards Borgo San Sepolcro, and 20 miles on the San Stefano side and that of Casentino.	62
PIGNA,	Corsica,	1858.	1
PIGNEROL,		1753; 1808, extended over the whole Rhone Valley, + 76; 1809 + 4; 1810; 1811 + 2; 1812; 1828 + 1; 1854; 1857 + 1; 1858 + 6 + 2 S.E.–N.W.; 1866; 1868 N.–S. + 1; 1871 + 3; 1878 E.–W. + 1; 1881 N.W.–S.E.	112
PIKERMI,	South of Pentelicus, Attica,	1858 + 1.	2
PILIS,	Hungary,	1826.	1
PINKAFELD,	Eisenbourg Com., Hungary,	1865 W.–E.	1
PINZGAU,	Carinthia,	1862 + 2 W.–E.	3
PIONSAT,	Auvergne,	1788 + 3.	4
PIRANGE,	Belgium,	1865.	1
PIREUS,		1859; 1861 + 1.	3
PIRNA,	Saxony,	1872.	1
PISA,		1168; 1322; 1349; 1414; **1481** + 2; 1494 + 3; 1597; 1740; 1742 + 2; 1767 + 1; 1813; 1814; 1843 + 2; 1845 + 2; 1846 + 1 N.W.–S.E., very violent, + 9; 1847 + 2 + 1 N.–S.; 1848 + 8; 1849 + 3; 1850 N.–S. + 3; 1851 + 3; 1852 + 3; 1853 + 4; 1854; 1860; 1871 + 4; 1878.	79
PISANA,	Sicily,	1869 + 4.	5
PISENA,	Illyria,	1870.	1
PISKE,	Hungary,	1834; 1860 + 1.	3
PISTOIA,		1289; 1293, recurred for 24 days, + 24; 1298; 1759; 1765; *1779* + 1; 1783; 1819; 1843 + 2; 1847 + 2 + 1 N.–S.; 1853 E.–W.	41
PITEA,	West Bothnia, Sweden,	1765 + 1; 1882 N.E.–S.W. + 1.	4

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
PITTIN, . . . near	Neukirchin, Lower Austria, .	1876 + 1.	2
PITTRICHIE, . . .	Aberdeen, Scotland, . .	1842.	1
PIZZO, ...	Calabria, ...	1659 ; 1869 + 1 ; 1870.	4
PIZZO DI UCELLO, .	Apuan Alps, . . .	1837.	1
PLACENTIA = PIACENZA,	. . . . .	1438 ; 1473 ; 1786 ; (1856 + 1) N.W.–S.E.	5
PLAGNES, Les, . .	Haute Savoie, . . .	1868.	1
PLAN, ...	Austria, ...	1855 + 3 ; 1856 + 1.	6
PLANDEBAIX, . . .	Drôme, ...	1856.	1
PLANINA, . . .	Carinthia, ...	1834.	1
PLATT, ...	Tyrol, ...	1859 S.W.–N.E.	1
PLAUEN, ...	Voigtland, Erzgebirge, .	1701 ; 1770 + 7 ; 1788 + 1 ; *1789* E.–W. ; 1819 ; 1859 S.W.–N.E. + 1 ; (1862 + 1) N.–S. ; 1875 E.–W. + 1.	19
PLENŒUF, . . .	Côtes du Nord, . . .	1773 N.W.–N.E. + 1.	2
PLESS, ...	Great Russia, . . .	1785.	1
PLESSIS, Chateau de, .	4 miles from Montdidier, [Somme,	1756 + 1.	2
PLŒRMEL, . . .	Morbihan, ...	1868.	1
PLOMBIÈRES, . . .	Vosges, ...	1821 S.–N. + 3 ; 1851 W.N.W.–E.S.E. ; 1859 + 1.	7
PLOO MOUNTAIN, . .	Greece, ...	1853.	1
PLYMOUTH, . . .	. . . . .	1757 ; 1811 ; 1847 ; 1853 ; 1858 ; 1863.	6
PODGRAJE, . . near	Klana, Illyria, . . .	1870 + 1.	2
PODOGRITZA, . . .	23 miles North of Scutari, [Albania,	1876 + 1 N.–S.	2
PŒLLAU, ...	Styria, ...	1865 N.W.–S.E. + 1 E.–N.W.	2
PŒT LAVUL, . . .	Drôme, ...	1852.	1
POGGIBONSI, . . .	Sienna, Italy, . . .	1804 ; 1869 + 5.	7
POGGIO-CHERICI, . .	Arezzo Province, . . .	1867 W.–E. + 1.	2
POITIERS, ...	. . . . .	1644 + 3 ; 1772 ; (1806 + 1) S.–N. 1828 ; 1832 ; 1836 ; *1837* + 1 ; 1844 N.–S. ; 1869 + 2 ; 1880.	17
POITOU, ...	. . . . .	1684 + 3 ; 1749, extended from Porstou beyond Luçon to neighbourhood of Blois, 60 leagues ; 1755 ; 1776 + 3 ; 1780 + 3.	14
POLA, ...	Istria, ...	1870 E.–W. + 1 N.E.–S.W. + 1 ; 1873 ; 1875 ; 1880 ; 1881 W.–E.	7
POLAGO TORRES, . .	Beluno Ter., . . .	1873.	1
POLAND, ...	. . . . .	1000 ; 1016 ; 1199 + 4, lasted several days, extended to Constantinople ; 1257 ; 1258 ; 1303 ; 1348 ; 1357 ; 1443 ; 1680 ; 1690 ; 1731, said to have extended from Poland to the Pyrénées, passing at Bâle ; 1786 + 1.	18
POLLAU, ...	Styria, ...	1865 N.W. + 1 + 1 N.W.–S.E.	3
POLCH, ...	Rhenish Prussia, . .	1869 W.–E. + 2.	3
POLESTINA, . . .	Calabria, ...	1881.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
POLI, ...	Rome, ...	1844.	1
POLICASTRO, . . .	Calabria, ...	1832.	1
POLIGNANO, . . .	Terra di Barri, . . .	1857.	1
POLISTINA, . . .	Calabria, ...	1869.	1
POLLA LA, . . .	Principato C., . . .	1856 ; 1857 ; 1858 + 34 + 1 N.E.–S.W.	38
POLLICA, . . .	,, . . .	1854.	1
POLLINA, . . .	Albania, ...	(1866 + 19) S.–N. + 13.	33
POLLEUR, . . .	Belgium, ...	1867.	1
POLU, ...	Illyria, ...	1870 E.–W.	1
POLYPHENGOS, . .	Corinth Isthmus, . .	1861.	1
POLIZZI, ...	Palermo, Sicily, . . .	1818.	1
POMAJA, ...	Pisa Ter., ...	1852.	1
POMERANCE, . . .	Lagoni, Tuscany, . .	1846 ; 1853.	2
POMPEI, ...	. . . . .	A. D. 63.	1
PONS, ...	Charente Inférieure, . .	1750.	1
PONTAFEL, . . .	Carinthia, ...	1855 W.–E. ; 1868 ; 1876 + 1 S.W.–N.E. + 1 ; 1878 + 1 ; 1879 S.E.–N.W. + 1 ; 1880 W.–E. ; 1881 S.–N.	11
PONTARLIER, . . .	Doubs, ...	1848 ; 1855 ; 1876.	3
PONTE, ...	Grisons, ...	1882 + 1.	2
PONTEBBA, . . .	Udine, ...	1881 N.–S. + 1 ; 1882.	3
PONTE DELLE ALPE, .	. . . . .	1873.	1
PONTE D'ERA, . .	Italy, ...	1846 + 1.	2
PONTE VEDRA, . .	Galicia, Spain, . . .	1857.	1
PONT-FERRADA, . .	Leon Province, Spain, . .	1829.	1
PONTGIBAUT, . .	Puy de Dôme, Auvergne, .	1855 E.–W. ; 1857 N.–S. + 3.	5
PONT LEVAY, . .	Indre, ...	(1841 + 1) N.–S.	2
PONT L'EVÊQUE, . .	Calvados, ...	1757 + 1.	2
PONTREMOLA, . .	Sicily, ...	1790.	1
PORTREMOLI, . .	Parma, Italy, . . .	1834, very violent, + 27 ; 1835 ; 1849 ; 1850 ; 1855 S.–N. ; 1859 + 1.	34
PONTRIEUX, . . .	Côtes du Nord, . . .	1853.	1
PONTROY, . . .	Alsace, ...	(1829 + 3) N.–S.	4
PONTUS, ...	. . . . .	A. D. 499.	1
PONZA Islands, . .	. . . . .	*1827 + 1*, direction from Ponza to Ischia.	2
PO VALLEY, . . .	. . . . .	1874 + 3.	4
POOLE, ...	. . . . .	1750 ; 1834.	2
POPPLESDORF, . .	Bonn Canton, Rh. Prussia, .	1869 + 1 W.–E.	2
POPPI, ...	Tuscany, Arezzo, . .	1787 + 1.	2
PORDENONE, . . .	Venetia.	1881.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
PORENTIGRAT, . .	Puy de Dôme, . . .	1881.	1
POREPROWNAJA, . .	Caucasus, ...	1870.	1
PORLETO, . . .	Piedmont, ...	1845 S.–N.	1
PORRETTA, . . .	Bologna, ...	1864 + 48, had their origin in the little volcanoes of Poretta and in the gazeous springs found there.	49
PORONTRIN, . . .	Berne Canton, . . .	1721; 1817; 1854 E.–W.	3
POROS, ...	Greece, ...	1860.	1
PORSGSUND, . . .	Norway, ...	1834 + 2; 1851.	4
PORTASKAIG, . . .	Scotland, ...	1880.	1
PORTA WESTPHALICA,	Weser Valley, . . .	1868.	1
PORTELÉK, . . .	Hungary, ...	1829.	1
PORTELLA DELLE CELLE,	Sicily, ...	1871.	1
PORT GLASGOW, . .	. . . . .	1820.	1
PORTI, ...	Sicily, ...	1780.	1
PORTICI, ...	Naples, ...	1760; 1761; 1779 + 1; 1847.	5
PORTIMAN, . . .	Portugal, ...	1722, and all the coast south from Cape St. Vincent.	1
PORT MAURICE, . .	. . . . .	1828; 1831 E.–W. + 2; 1854 + 2; 1858; 1871.	9
PORTO CANNONE, . .	Italy, ...	1821 + 7.	8
PORTO FERRAJO, . .	Elba, ...	1846.	1
PORT RIEUX, . . .	Brittany, ...	1800.	1
PORT ROYAL, . . .	Spain, ...	1773.	1
PORTREE, . . .	Scotland, ...	1880.	1
PORTSMOUTH, . .	. . . . .	1691; 1734; 1750; 1811; 1824; 1834 + 1; 1853, surface shaken, estimated at 20,000 ms.	8
PORTUGAL, . . .	. . . . .	1146; 1504 + 3; 1531; 1719; 1755, great Lisbon earthquake; 1807; 1821; 1847 + 4.	15
,, NORTHERN,	. . . . .	1858 + 1, very violent.	2
,, CENTRAL,	. . . . .	1858.	1
PORTUGUESE COAST, .	. . . . .	1722, all the coast south from Cape St. Vincent; 1761.	2
PORTULA, . . .	Upper Italy, . . .	1881.	1
POSCHIAVO, . . .	Sondrio, Grisons, Switzerland,	1860; 1861 W.–E.; 1871 + 1.	4
PÖSSNITZ, . . .	Styria, ...	1823; 1880.	2
POSTA VILLAGE, . .	Sora, Terra di Lavoro,	1851; 1874.	2
POTENZA, . . .	Basilicata, ...	1812; 1826 N.–S. + 2, felt simultaneously in the Campagna 10 miles to the W., and at Salerno; 1841; 1842; 1844 + 4; 1845 N.–S. + 2; 1846 + 1; 1853 + 1; 1854 + 1; 1855 + 3; *1857 + 2* E.–W. + 10; 1858 + 42 + 1 N.E.–S.W. + 1; 1860; 1861 + 3; 1869; 1874 + 1; 1875.	91
PÖTSCHACH, . . .	Carniola, ...	(1882 + 1) S.E.–N.W.	2
POTTENSTEIN, . .	Lower Austria, . . .	1874.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
POTURNIJA,	Hungary,	1786.	1
POUILLY,	Côte d'Or,	1838; 1862.	2
POYANS,	Haute Saône,	1862 E.–W.	1
POZEGA,	Sclavonia,	1858 + 3.	4
POZZODIGOTTI,	North Sicily,	1717.	1
POZZUOLI,	Naples,	1537; 1538 + 20; 1582; 1594; 1832 + 1; 1856; 1858 + 1.	29
PRACCHIA,	Bologna,	1864.	1
PRADES,	Rousillon,	1772.	1
PRADIES,	Cataluña,	1845 + 1.	2
PRADGERHOF,	Styria,	1880 + 1.	2
PRAGUE,		1329; 1615; 1756 + 1; 1784 + 1 1821 + 3; 1872 + 1; 1876.	13
PRANDEN,	Austria,	1765 + 2.	3
PRAROMAN,	Jura,	1846 S.W.–N.E. + 1.	2
PRATO,	Firenze,	1847.	1
PRATOLA,	Abruzzo,	1855.	1
PRAUTHOY,	Haute Marne,	1862 + 1.	2
PREDIL,	Carniola,	1876.	1
PREDOPPIO,	Forli,	1870.	1
PREGARIE,	Istria,	1861.	4
PREGARTEN,	Upper Austria,	1868 + 1; 1869 + 1.	1
PREGRATTEN,	Tyrol,	1862 + 4.	5
PREJANO,	Old Castille, Spain,	1817.	1
PREM,	Illyria,	1870.	1
PRESCOT,	Lancashire,	1843.	1
PRESSBOURG,	Hungary,	1766; 1768; (1774 + 2) N.W.–S.W.; 1781; 1783; 1788; 1791 + 3; 1806 + 1; 1813 + 1; 1849 S.W.–N.E.; 1851; 1862 N.W.–S.E. + 1; 1864 N.W.–S.E.; (1866 + 1) S.–N.; 1868 N.–S. E.–W.; 1876.	25
PRESTON,	Lancashire,	1843.	1
PREUSCHDOF, near	Wörth, Alsace,	1825.	1
PREVALI,	Carinthia,	1857 W.–E.	1
PREVESA,	Albania,	1825; 1826; 1856 + 1; 1858 + 4; 1860 N.–S. + 1; 1869.	12
PRIBOJ,	Bosnia,	1882 W.–E.	1
PRIMIERO,	Tyrol,	1872 S.–N.	1
PRINCES'S ISLAND,	Sea of Marmora,	1857.	1
PRINKLES MINES,	Bohemia,	1824.	1
PRISCHIB,	Lat. 38° 9′ Long. 46° 15′ S.W. Russia,	(1863 + 2) S.–N.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
PRISSÉ, ...	Environs of Macon, . .	1881.	1
PRITSCHAPEL, . near	Eidlitz, Bohemia, . .	1862 + 2.	3
PRIVAS, ...	Ardeche, ...	1873.	1
PRODURRA, . . .	Bologna, ...	1864.	1
PROJEDOR, . . .	Military Telegraph Station, [Bosnia,	1882.	1
PROKIKÉ, . . .	South of Fiume, Illyria, .	1870.	1
PROMONTOGUO, . .	Grisons, ...	1882 + 1 N.–S.	2
PROTSCHNOOKAP, .	Caucasus, ...	1869 ; 1870.	2
PROVENCE, LA, . .	. . . . .	1682 + 3.	4
PRUMMERN, . . .	Rhenish Prussia, . . .	1873 + 6.	7
PUAS, ...	Belluno Ter., . . .	1873.	1
PUCHACHE, . . near	Leipzig, Saxony, . .	1832.	1
PUGET-THENIERS, .	Alpes Maritimes, . . .	(1850 + 1) S.W.–N.W.	2
PUERNO, ...	Kingdom of Naples, . .	1857.	1
PUGLIA, LA, . . .	*See* La Puglia, . . .		
PULGARN, . . .	Upper Austria, . . .	1785 + 4.	5
PULKOWA Observatory,	. . . . .	1846 ; 1849 ; 1861 ; 1862 ; 1867.	5
PULLY, ...	Berne, Switzerland, . .	1880.	1
PUNTO D'OSTRO, . .	Dalmatia, ...	1881.	1
PÜRKERSDORF, . .	Vienna District, . . .	1875, limits—Raab, to the N., Klausen, Leopoldsdorf, to the S., Salmandsdorf, to the E.	1
PUSCHLAU, . . .	Grisons, ...	(1871 + 1) S.–N.	2
PUSZTA-BAKTA, . .	Beregh Com., Hungary .	1859 N.E.–S.W.	1
PUTZCHEN, . . .	Bonn C., Rhenish Prussia, .	1828 + 2 ; 1869.	4
PUY, LE, ...	Haute Loire, . . .	1772 + 2 ; 1855 + 2 N.E.–S.W. ; 1857 ; (1868 + 2) E.–W. ; 1869 ; 1881.	12
PUY DE DÔME, . .	. . . . .	1807 ; 1881.	2
PUY DE DÔME Department,	. . . . .	1881 N.E.–S.W.	1
PYLOS, ...	Peloponessus, . . .	1865 + 1 W.–E.	2
PYRÉNÉES, . . .	. . . . .	579 ; 1378 ; 1580 ; 1660 ; 1678 ; 1731 ; 1750 ; 1791 ; 1840 + 3 ; 1850, extended all along the foot of the Pyrénées from Bagnieres to Pau ; 1850 ; 1854.	15
PYRÉNÉES, Northern Slope of,	. . . . .	1765.	1
„ Southern „	„	1852.	1
PYRÉNÉES ORIENTALES, Department,	. . .	1824 ; 1837. *See* Eastern Pyrénées.	2
PYRGOS, ...	Peloponessus, . . .	1840 ; 1841 + 3 ; 1842 + 3.	9
PYRNA, ...	Corinth Gulf, . . .	1870.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
QUADERNA,	Bologna District,	1880 + 2; 1881 + 5 + 1 N.W.–S.E.	10
QUELUS,	Portugal,	1788.	1
QUERZOLA, SALSA DI,	Reggio Province,	1881 + 4.	5
QUINÇAY, near	Blois,	(1841 + 1) W.–E.	2
RAAB,	Hungary,	1763 + 1, simultaneously at Comorn, + 1; 1764; 1765 + 1; 1783; 1860; 1875.	9
RAC,	Drôme,	1873 + 3.	4
RACCOLANO,	Udine,	1876.	1
RADEIN,	Styria,	1877.	1
RADELFINGEN,	Berne Canton,	1882 W.–E.	1
RADICOFANI,	Sienna, Italy,	1843; 1861.	2
RADKERSBURG,	Styria,	1880.	1
RADMANSDORF,	Carinthia,	1869 + 2 + 1; 1870 + 1; 1873.	6
RADOLFSZELL,	Constantine Lake,	1875.	1
RADSTADT,	Austria,	1737; 1787; 1855 W.–E.	3
RAGATZ,	St. Gall Canton,	1853; (1881 + 1) N.–S.	3
RAGUSA,		1481 + 1; 1520; 1626; 1639; 1667 E.–W., very violent—town destroyed; 1668; 1773 + 1; 1780 E.–W. + 2; 1823, 15 miles radius, + 1; 1843 + 97 + 4 N.E.–S.W.; 1844 + 48; 1845 + 9; 1849 + 3; 1850, very violent, + 88 + 2 E.–W. + 2 W.–E.; 1851 + 72, as at Stagno Piccolo, + 1; 1852 E.–W. + 4; 1853 + 5 + 1 E.–N.E. + 1 E.–W. + 2 N.E.–S.W.; 1854 N.–S. + 9 + 1 N.E.–S.W.; 1855 + 13; 1856 + 7 + 1 S.–N.; 1857 + 11; 1859 + 1; 1860 + 6; 1864, violent, + 1; 1868; 1869 + 60; 1870 + 2; 1873; 1876 + 5; 1880 N.–S.; 1881.	492
RAGUSA VECCHIA,		1843.	1
RAIBL,	Venetia,	1871; 1876; 1879 N.W.–S.E.; (1882 + 1) E.–W.	5
RAJECZ,	South of Sillian, Hungary,	1845.	1
RAKOVAC, near	Carlstadt, Croatia,	(1870 + 2) S.W.–N.E.; (1872 + 2) S.W.–N.E., simultaneously at Agram.	6
RAMAH,	Palestine,	1546.	1
RAMBOUILLET,	Seine et Oise,	1841 W.–E. + 1.	2
RAMELTON,	Scotland,	1880.	1
RAMERSDORF,	Bonn Canton, Rh. Prussia,	1856; 1869.	2
RAMLEH,	South-Western Palestine,	1069.	1
RAMPITZ,	Brandenbourg, Prussia,	1752.	1
RAMSGATE,		1831; 1858.	2
RAMSLAU,	Poland,	1786 + 3.	4
RAMSTEIN,	Bavaria,	1869 + 2.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
RANDA,	Valais,	1855 + 1; 1862.	3
RANDAZZO,	Etna,	1874 + 3; 1882 + 5.	10
RANDENRATH,	Rhine Valley,	1873.	1
RANDERS,	Tyrol,	1868.	1
RANEN,	Heligoland,	1834 + 1.	2
RANI Village,	Styria,	1836, completely destroyed.	1
RANKENBERG,	Bonn C., Rhenish Prussia,	1869 N.N.W.–S.S.E.	1
RANN,	Croatia,	1860 S.–N. + 2; 1881.	4
RANSBURG,	Denmark,	1755.	1
RAPELLA,	Basilicata,	1851 + 5; 1852 + 2; 1853; 1855 + 5.	16
RAPHOE,	Ireland,	1880.	1
RAPOLANO,	Sienna District, Italy,	1847 + 2.	3
RAPPERSWEIL,	Switzerland,	1861; 1877 + 1.	3
RAROGNE,	Valais,	1855.	1
RAS-EL-AIN,	Constantine Prov., Algeria,	1862 E.–W.	1
RASPENAU,	Silesia, Prussia,	1799.	1
RASTATT,	Baden,	1880, connected with the Agram earthquake.	1
RATHMINES,	Dublin,	1863.	1
RATISBON,		1774; 1787 + 1; 1872.	4
RATIBOR,	Silesia, Prussia,	1774; 1785; 1786 + 3.	6
RATTENBERG,	Tyrol,	1865; 1877 + 1.	3
RAUBTHAL,	Styria,	1865 S.W.–N.E.	1
RAUN,	Lower Styria,	1853 E.–W. + 1.	2
RAUNHEIM,	Darmstadt,	1869 + 4.	5
RAVENNA,		467; 1448; 1479; 1510; 1661; 1672; 1780; 1861; 1870 + 6; 1871 + 13; 1872; 1874 + 2; 1875; 1876 + 5; 1881 + 1.	42
RAVENSBURG,	Würtemberg,	1855 + 1 E.–W.; 1861.	3
READING,		1755.	1
REATE,	Sabine Country,	B.C. 80.	1
RECACIUNE,	Roumania,	1880.	1
RECKIGEN,	Valais,	1865.	1
REDBURG,	Rhine Valley,	1868.	1
REDRUTH,		1757; 1842; 1859; 1860.	4
REDSCHITZ,	Bohemia,	1860.	1
RED SEA (opposite Aden),		1861.	1
RED SEA,	East Coast of,	1870, earthquake on same day, and nearly same hour, in the northern part of the Grecian Archipelago, in Sicily and Southern Italy.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
REGENSBURG = Ratisbon,	. . . . .	*See* Ratisbon.	
REGGIO, ...	Calabria, ...	1230; 1345; 1638; 1710 + 2; 1770 + 16; 1783; 1784; 1788; 1806; 1810; 1811; 1818 + 1; 1830 + 1; 1831; 1832 + 2; 1839 + 66; 1841 + 3; 1843 + 8 + 1 N.E.–S.W.; 1844 + 9 + 1 N.E.–S.W.; 1845 + 4; 1846 + 6; 1847 + 23 + 1 N.E.–S.W.; 1849 S.–S.W. + 2; 1850 + 10; 1851 S.W.–N.E. + 12; 1852 + 22; 1853 + 6 + 607 (786 shocks from 1836 to 1853); 1855 + 2; 1856: 1857 + 1; 1858 + 8; 1864; 1865; 1866 + 2; 1868 + 2; 1869 + 2; 1870 S.W.–N.E. + 5; 1871 + 1; 1876; 1879 + 1; 1881.	861
REGGIO, ...	Emilia, ...	1570 + 84; 1832 + 3; 1848 E.–W. + 4; 1850; 1870; 1880; 1881.	98
REGGIOLO, . . .	Modena, ...	1873 + 1.	2
REGNANO, . . .	Reggio Province, . .	1881 + 1.	2
REHKAUSEN, . . near	Naumburg, ...	1830 + 1.	2
REICHELSHEIM, . .	Darmstadt, ...	1869 + 4.	5
REICHENAU, . . .	Lower Austria, . . .	1870; 1874 + 1 S.–N. + 1 E.–W.; 1881.	5
REICHENBACH, . .	Odenwald, ...	1869 + 4; 1871 + 22 + 1 S.W.–N.E.; 1873 + 2 S.W.–N.E.; 1875; 1876.	34
REICHENBERG, . .	Rhine Valley, . . .	1869 + 1.	2
REICHENBURG, . .	Styria, ...	1865; 1872.	2
REICHENHALL, . .	9 miles S.W. of Saltzbourg,	(1844 + 1) S.–W.; 1851; 1876.	4
REIFFENBERG, . near	Frankfort-on-Main, [Bavaria, . .	1619; 1828.	2
REIFNIGG = REIFNITZ,	Carniola, ...	1881.	1
REIGATE, . . .	. . . . .	1551.	1
REINERZ, . . .	Silesia, Prussia, . . .	1860.	1
REITZENHAIN, . .	Rheingau, Nassau, . .	1869.	1
REKAS, . . . near	Temesvar, ...	1866.	1
REKAWINKEL, . .	Vienna District, . . .	1875.	1
RELIZANE, . . .	Algeria, ...	1862 + 6; 1863; 1864; 1865.	10
REMAGEN, . . .	Rhenish Prussia, . . .	(1828 + 2) N.W.–S.E.; 1869 N.W.–S.E. + 3 + 1 S.–N.; 1873; 1878 + 1.	11
REMETE, . . . near	Agram, ...	1880.	1
REMIREMONT, . .	Vosges, ...	1862; (1821 + 3) S.–N.; 1828; 1831 S.W.–N.E.; 1851; 1858 N.–S.	9
REMUS, ...	Grisons, ...	(1868 + 1) N.E.–S.W.	2
RENGSDORF, . . .	Neuwied C., Rhenish Prussia,	(1869 + 1) S.E.–N.W.	2
RENI, ...	Moldavia, ...	1829 + 1; 1838 + 3.	6
RENNES, ...	Ille et Vilaine, . . .	1843; 1853.	2
RENO River Valley, .	Italy, ...	1881.	1
RENTI, . . . near	Seefeld, North Tyrol, . .	1856 S.–N.	1
RESIA Valley, . .	Udine, ...	1876 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
RESINA, . . . near	Naples, ...	1779; 1831; 1832; 1847; 1855; 1857, continuous vibrations; 1867 + 1; 1874; 1875;	10
RESIUTTA, . . .	Udine, ...	1881.	1
RESNIK, ...	Save River, ...	1880.	1
RETHEL, ...	Ardennes, ...	1775.	1
RETIMO, ...	Candia Island, . . .	1862; 1879 + 2.	4
RETTINGEN, . . .	Switzerland, . . .	1729.	1
REUSS, ...	Cataluña, ...	1845.	1
REUTH, ...	Zwickau C., Saxony, . .	1860 W.–E., and Voitzberg.	1
REUTLINGEN, . .	Würtemberg, . . .	1828; (1855 + 2) N.–S.	4
REUTTLE, . . .	Tyrol, ...	1863 + 1.	2
REVEL, ...	Russia, ...	1869.	1
REVELLO, . . .	Piedmont, ...	1808 + 3.	4
REYKIAVIK, . . .	Iceland, ...	1810; 1846; 1847 + 4; 1860; 1868 + 4 + 9 E.N.E.–W.S.W.; 1870 S.W.–N.E. + 1; 1878 + 1; 1879 + 1.	28
RHAUNEN, between Nahe	River and Moselle River, Rh. [Prussia,	1869.	1
RHEGIUM = REGGIO, .	. . . . .	B. C. 95.	1
RHEIDT, ...	Sieg C., Rhenish Prussia, .	1869.	1
RHEINBACH, . . .	Rhenish Prussia, . . .	1869 W.–E. + 2.	3
RHEINBÖLLEN, between	Nahe River and Moselle River,	1869 + 2.	3
RHEINFELS FORTRESS,	ON THE RHINE, . . .	1784 + 1.	2
RHEINFELDEN, . .	Aargau Canton, . . .	1863; 1879 S.W.–N.E. + 1.	3
RHEIN HESSEN, . .	Darmstadt, ...	1869 E.S.E.–W.N.W.	1
RHEINTHAL, . . .	Switzerland, . . .	1821.	1
RHEINWYL, . . .	Solothurn C., . . .	1841 + 3.	4
RHEINZABERN, . .	Bavaria, ...	1880.	1
RHENISH PRUSSIA, .	. . . . .	1869, centre at Sieburg, exteneed over an area of which radius = 11·4 E. miles; 1878.	2
RHENS, ...	Rhenish Prussia, . .	1869.	1
RHETIERS, . . .	Ille et Vilaine, . . .	1853.	1
RHETIC ALPS, . .	. . . . .	1295.	1
RHINE, BANKS OF, . .	. . . . .	1755; 1869; 1873 + 2; 1881.	6
,, BASIN OF, . .	. . . . .	1846.	1
,, MIDDLE VALLEY OF,	. . . . .	1869; 1880, kept close to both banks of the river, extended to Bavarian Palatinate, part of Baden, and Würtemberg.	2
,, LOWER DISTRICT OF,	. . . . .	1755; 1873, centre at Herzogenrath, + 16, extended E. to Cologne, split there into two branches, one went towards Dusseldorf and Crefeld, the other towards Bonn and Remagen—extended to Brussels, S. to Aachen, N. to Hemsberg; 1876; 1878.	19

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
RHINE, PROVINCE (*see* RHENISH PRUSSIA).			
,, VALLEY OF, . .	. . . . .	1828 + 1, in a line N.–S. from Metz to Aix-la-Chapelle.	2
RHINAU, ...	Zurich Canton, . . .	1838.	1
RHODES ISLAND, . .	. . . . .	B. C. 224, the Colossus thrown down; A. D. 150; 344; 1481; 1635, very violent; 1660; 1843 + 12 + 1 S.–N.; 1846; (*1851 + 12*) E.–W. + 180; 1852; 1853; (1855 + 1) E.–W. + 2 N.–S.; 1856 E.–W. + 6; 1857 + 5; 1858 + 11 + 1 E.–W. + 1 W.–E.; 1859 + 1 E.–W. + 1 W.–E. + 2; 1860 + 10; 1862 N.–S. + 2 + 1 W.–E.; (1863 + 1) E.–W. + 1 N.E.–S.W. + 1, very violent, + 30 + 2 S.–N. + 1, extended to the Dardanelles, to Sparta, Anthi, Jenidji, and Sarichtaban, + 6 E.–W.; 1864, violent, + 2 E.–W. + 2, extended to Makri, Anatolia, + 10 E.–W. + 5 + 3 S.–N. and E.–W.; 1865 + 20 + 1 N.–S.; 1866 + 10 + 1 N.W.–S.E. + 1 W.–E. + 5, extended 60 miles to sea; 1868 + 1; 1869 N.N.W.–S.S.E.; 1870; 1874.	377
RHODEZ, ...	. . . . .	1750.	1
RHŒZUENS, . . .	Grisons, ...	1855.	1
RHONASGEK, . . .	Marmaros C., Hungary, .	1858 E.–W.; 1859 S.E.–N.W. + 1 E.–W.	3
RHONE, BANKS OF, . .	. . . . .	1873 + 1.	2
,, RIGHT BANK OF,	. . . . .	1873 + 1.	2
,, BASIN OF, . .	. . . . .	1866.	1
,, DEPARTMENT OF,	. . . . .	1843; 1851; 1877.	3
,, SOURCE OF LAKE OF	GENEVA, ...	1881.	1
RIBAGORCA DISTRICT,	Aragon, ...	1372 + 1, very violent, mountains reduced to ruins.	2
RICCIA, LA, . . .	Molise, Italy, . . .	1752; 1754; 1781; 1799 + 3; 1801; 1829 + 14.	23
RICCIOLI, . . .	Tuscany, ...	*1753 + 1.*	2
RICHEBOURG, . .	Nantes Arrond., . . .	1877.	1
RICHENAU, . . near	Constance, ...	849.	1
RICHTERSWEIL, . .	Zurich Canton, . . .	1861.	1
RIDSWOOLD, . . .	Norway, ...	1865.	1
RIED, ...	Upper Austria, . . .	1868 + 1; 1869 + 1.	4
RIESBACH, . . .	Faubourg of Zurich, . .	1880.	1
RIESENGEBIRGE, . .	. . . . .	1799.	1
RIETI, ...	. . . . .	1298; 1302; 1303; 1694; 1785; 1786 + 1. 1821.	8
RIFFEL, ...	Switzerland, . . .	1855.	1
RIGA, ...	. . . . .	1870 + 1.	2
RILLIEUX, . . .	Ain, ...	1857.	1
RIMBACH, . . .	Odenwald, Hesse, . .	1867.	1
RIMINI, ...	. . . . .	1306; *1672*, 1500 people perished; 1691 + 3; 1756; 1780; 1781; 1786 + 9; 1787 + 3; 1853 + 1; 1874.	26
RINDENMOOS, . .	Würtemberg, . . .	1846.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
RINGGENBERG,	Brienzer Zee,	1880 + 1.	2
RINGKJŒBING,	Jutland,	1867 ; 1882.	2
RINO RIVER VALLEY,	Bergamo,	1881.	1
RIOJA DISTRICT,	Spain,	1817 + 115 (116 shocks in three months).	121
RIOLO, near	Bologna,	1880 + 2.	3
RIO NEGRO, / RIO NERO,	Basilicata,	1851 E.–W. + 7 ; 1852 + 2 ; 1853 ; 1855 + 5.	18
RIOUM,	Auvergne,	1753 N.–S. ; 1785 ; 1803 + 3 ; 1838.	7
RIPACANDIDA,	Basilicata,	1851.	1
RIPARBELLA,	Pisa,	1846 ; 1848 + 1.	3
RIPASTO,	Etna,	1874 + 3 ; 1877 + 3.	8
RIPON,		1796 ; 1827.	2
RIPPOLDSAU,	Baden Duchy,	1871 S.–N. + 1.	2
RIPRAFATTA, near	Pisa,	1854.	1
RISANO,	Dalmatia,	1877 ; 1880.	2
RISSEGG,	Würtemberg,	1846.	1
RIVA,	Tyrol,	(1870 + 2) S.W.–N.E. + 1 ; 1873 + 1 ; 1880 W.–E.	7
RIVA,	Lagc di Garda,	1868 N.–S. ; 1873 + 1.	3
RIVA, / RIVA VAL D'OBBIA,	Piedmont,	1880 + 2 ; 1881.	4
RIVAZ,	Geneva Lake,	1881.	1
RIVE DE GIER,		1861 + 1.	2
RIVESALTES,	Pyrénées Orientales,	1797.	1
RIVIERA, LA,		1860.	1
RIVIERA, LIGURIAN (WESTERN),		1871.	1
RIVIÈRE THILON,	Normandy,	1878.	1
RIVOLI,	Torino,	1825.	1
ROANNE,	Auvergne,	1833 ; 1857.	2
ROCCA,	Abruzzi,	1765.	1
ROCCABERNARDO,	Calabria,	1832.	1
ROCCA DI NETO,	,,	1832.	1
ROCCA DI PAPA,		1870 + 1 ; 1871 + 1 ; 1880 + 1 ; 1881 + 6.	13
ROCHDALE,		1864.	1
ROCHE-CEVINS, LA,	Maurienne,	1847.	1
ROCHEFORT,		1780 ; 1799 ; 1829 ; 1852.	4
ROCHELLE,		1799 ; 1852.	2
ROCHETTE,	Maurienne,	1847 + 1.	2
ROCHLITZ,	Zwickau V., Saxony,	1[illegible].	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ROCKELBACH, . .	Odenwald, ...	1872 S.E.–N.W.	1
ROCROY, ...	. . . . .	1755 + 2.	3
RODAU, ...	Saxony, ...	1869 ; 1871 + 3.	5
RÖDELHEIM, . . .	Frankfurt, ...	1868.	1
RODENBACH, . . .	Cassel, ...	1869 + 1.	2
RODGEN, . . . near	Giessen, ...	1869 + 2 S.–N.	3
RODI, ...	Capitanata, ...	1851 ; 1855 ; 1857 ; 1858 + 1.	5
RODOPE MOUNTAINS, .	. . . . .	1880 + 1.	2
RODOSTO, . . .	Rumili, Turkey, . . .	1865 N.–S. ; 1868 ; 1869 + 1 E.–W. + 1 ; 1870 ; 1871.	7
ROGLIANO, . . .	Calabria Citra, . . .	1846.	1
ROHITSCH, . . .	Styria, ...	1877.	1
ROHRBERG, . . .	Odenwald, ...	1875.	1
ROHRDORF, . . .	Saxony, ...	1875 ; 1877.	2
ROHRICHT, . . .	Muhlvierta, Austria, . .	1868.	1
ROHSICH, . . .	Upper Austria, . . .	1867.	1
ROKEMBERG, . . .	Styria, ...	1838.	1
ROLANDSEK, . . .	Bonn C., Rhenish Prussia, .	1869 W.–E.	1
ROLLE, ...	Vaud Canton, Switzerland, .	(1847 + 5) S.W.–N.E. ; 1879 ; 1882.	8
ROMAGNA, . . .	. . . . .	**1353** + 2, and all along the coast to Constantinople ; 1428 ; 1661 ; 1750 ; 1781 + 2 ; 1783 ; 1801 ; 1802 ; 1831 + 1 ; 1854 ; 1870 + 1 ; 1881 + 4 + 1, centre between Florence and Bologna, + 1.	24
ROMAGNAT, . . .	Puy de Dôme, . . .	1877.	1
ROMANSHORN, . .	Thurgau Canton, . . .	1858.	1
ROMAN TERRITORY, .	. . . . .	B.C. 459–432.	1
ROME, . . .	. . . . .	B.C. 197 ; 164 ; A.D. 15 ; 223, very violent ; 262, very violent—extended to Lybia and Asia Minor ; 336 ; 344 ; 382 ; 408 ; 442 ; 477 ; 557, also at Constantinople ; 586 ; 789 ; 847 ; 896 ; 911 ; 1005 ; 1017 ; 1100 ; 1143 ; 1189 ; 1231 ; 1256 ; 1287 ; 1292 ; 1321 ; 1328, shocks continued for some months ; 1348 + 1 ; 1350 ; 1355 ; *1403*, 1448 ; 1456 ; 1463 ; 1484 ; 1624 ; 1654 ; 1662 ; 1695 + 5 ; 1702 ; *1703*, extended from Rome to Naples and Aquila in a line running from N. a little W. to S. a little E. along the Appenines + 74 + 1 N.–S. ; 1704 ; 1706 + 1 ; 1712 ; 1719 ; 1730 ; 1750 + 5 ; 1751 + 1 ; 1752 ; 1754 + 3 + 1 ; 1755 ; 1762 ; 1767 ; 1777 ; 1778 ; 1782 ; 1783 ; 1785, extended 60 miles along the Appenines + 10 + 3 N.E.–S.W. ; 1786 + 6 ; 1787 + 3 ; 1788 ; 1791 + 1 ; 1799 + 3 ; *1805* + 2, extended to Naples ; 1805 ; 1806 ; 1811 + 1 ; 1812 W.–E. + 2 ; 1818 ; (1819 + 1) S.E.–N.W. ; 1823 ; 1828 ; 1832 + 4 ; 1834 ; 1835 + 1 ; 1836 ; 1839 ; (1844 + 3) S.E. ; 1845 + 3 ; 1846 ; 1847 ; *1848* N.–S. + 4 ; 1849 + 4 ; 1853 E.–W. ; 1857 + 2 ; (1858 + 5) N.N.W.–S.S.E. + 10 + 4 N.–S. + 1 E.–W. ;	319

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ROME—*continued*, . .	. . . . .	1859 + 8 + 2 E.–W. ; 1860 + 2 + 2 N.N.E.–S.S.W ; (1861 + 2) N.N.E.–S.S.W. + 2 E.–W. + 3 S.W.–N.E. ; 1862 N.E.–S.W. + 2 S.S.W. + 1 N.–S. ; 1866 S.S.W.–N.N.E. ; (1867 + 3) E.–W. ; 1869 ; (1871 + 2) N.N.W.–S.S.E. ; 1873 + 4 + 1 N.W.–S.E. + 1 N.E.–S.W. ; 1876 ; 1877 ; 1879 + 5 ; 1880 + 2 ; 1881 E.–W. + 10 ; 1882.	
ROMERIKE, . .	Norway, ...	1875.	1
ROMORANTIN, . .	Loir et Cher, . . .	1845 + 1.	2
ROMSDORF, . . .	Linnep C., Rhenish Prussia,	1880.	1
RONCEUX, . . .	Vosges, ...	1784.	1
RONCO VALLEY, . .	Romagna, ...	1881.	1
RONDHELEM, . . .	20 leagues from Drontheim, [Norway,	1756.	1
RONDINELLA, . .	Sicily, ...	1865, the area of greatest shock formed an elongated band running W.N.W.–E.S.E. from the base of mountain Muscarillo to the sea, 5 km. long by 1 km. broad.	1
RÖNNE, ...	Bornholm Island, Denmark,	1872 ; 1875.	2
RONSDORF, . . .	16 miles East of Dusseldorf,	1875.	1
ROPOLANO, . . .	Sienna, ...	1847 + 2 ; 1849	4
ROQUEMAURE, . .	Gard, ...	1769 ; (1840 + 1) E.–W. ; 1855.	4
ROQUEVAIRE, . . .	Bouches du Rhone, . .	1846 + 1 ; 1873.	3
RORON, ...	Valais, ...	1855 ; 1856.	2
RORSCHACH, . . .	St. Gall Canton, . . .	1881 + 1.	2
ROSAS, ...	Cataluña, ...	1813.	1
ROSEGROVE, . . .	Lancashire and Yorkshire [Railway,	1869.	1
ROSELLIN, . . .	Neuss C., Rhenish Prussia, .	1869.	1
ROSENBACH, . . .	Carinthia, ...	1858.	1
ROSENBERG, . . .	Bohemian Frontier, . .	1818.	1
ROSENHEIM, . . .	Tyrol, ...	1873.	1
ROSETO, ...	Calabria, ...	1870.	1
ROSIGNANO, . . .	Pisa, ...	1846.	1
ROSINA, ...	Hungary, ...	1858 + 30 (30 shocks in first week, continued to February).	31
ROSSANA, . . } ROSSANO, . . }	Calabria Citra, . . .	**1555**, radius of 30 miles, + 3 ; 1825 + 1 ; **1836** ; 1841 + 1 ; 1846 ; 1851 N.–S. ; 1852 + 1 ; 1855 ; 1867 + 2 ; 1870 + 1 ; 1871.	20
ROSSANO VENETO, .	. . . . .	1881.	1
ROSSDORF, . . .	Rhine Valley, . . .	1869.	1
ROSSEGG, . . .	Carinthia, ...	1855 ; 1857 + 9 + 5 S.E.–S.W. ; 1858 + 3 + 3 S.W.–N.E., from April 2nd to 15th continuous movement, + 13, S.W.–N. and W.–E. + 12 ; 1858 S.W.–N.E. ; 1860 N.–S. + 1 N.S. ; 1863 ; 1880.	53
ROSSILLON, . . .	Ain, ...	1841.	1
ROSSNA, ...	. . . . .	1877.	1
ROTHEMBURG, . .	Hesse Cassel, . . .	1112 ; 1767.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ROTHENFLUH, . .	Basel Canton, . . .	1878.	1
ROTHENTHURM PASS, .	Transylvania, . . .	1860.	1
ROTHSAY, . . .	. . . . .	1880.	1
ROTHWEIL, . . .	Würtemberg, . . .	1855 + 2; 1871 + 1.	5
ROTSCHACH, . . .	Carinthia, ...	1855 W.E.	1
ROTTENMANN, . .	Styria, ...	1857 + 4; 1873.	6
ROTTERDAM, . . .	. . . . .	1755; 1802; 1803; 1804 + 1.	5
ROUEN, ...	. . . . .	1142; 1756; 1779; 1797; 1799; 1878.	6
ROUFFACH, . . .	Haut Rhin, ...	1818.	1
ROUGEGOUTTE, . .	Haut Rhin, ...	1843.	1
ROUGEMONT, . . .	Vaud Canton, . . .	1817; 1835; (1858 + 2) E.–W.	5
ROUGINE, . . .	Kieff Gov., Russia, . .	1868.	1
ROUMANIA, . . .	. . . . .	1750; 1880 + 1, over greater part of Roumania—the origin on one of the slopes of the Siebenburgher mountains along a line running towards them extending to Bessarabia.	3
ROUSILLON, . . .	Neighbourhood of Canigou, .	1431; 1755 + 5; 1761; 1824.	9
ROUSTCHOUK, . .	. . . . .	1802; 1862 E.–W.; (1868 + 2) N.–S. + 1; 1869 + 2; 1870; 1875; 1880.	12
ROUTIGNON, . . .	Pau, ...	1851 + 3 E.S.E.–W.N.W.	4
ROUTOT, ...	Eure, ...	1863.	1
ROVEREDO, . . .	. . . . .	1802; 1826; 1851 + 2; 1866 + 1; 1868 S.W.–N.E.; 1874; 1882 N.–S. + 1.	11
ROVETTA, . . .	Bergamo District, . .	1882.	1
ROVIGO, ...	. . . . .	1857 N.W.–S.E. + 2.	3
ROYAN, ...	Gironde, ...	1852.	1
ROYDON, ...	. . . . .	1551.	1
RUBIA, ...	Göritz District, . . .	1869 + 1.	2
RUDESHEIM, . . .	Nassau, ...	1869 + 1.	2
RUDOLFSTADT, . .	Bohemia, ...	1872.	1
RUDOLFSWERTH, . .	Carinthia, ...	1870 N.–S. + 1; 1875 + 1; 1877 + 2 + 1 N.W.–S.E. + 1 N.–S.; 1880 + 1; (1881 + 1) E.–W. + 2 N.E.–S.W.	15
RUE, ...	Jura, ...	1846.	1
RUGBY, ...	. . . . .	1868.	1
RUHR BASIN, . . .	. . . . .	1878.	1
RUM, ...	Tyrol, ...	1880.	1
RUMILI, ...	Turkey, ...	1860.	1
RUMILLY, . . .	Haute Savoye, . . .	1841; 1844 + 1; 1881.	4
RUNDERS, . . .	Grisons, ...	1813 + 1.	2
RUNKEL, ...	Nassau, ...	(1869 + 1) N.–S. + 1.	3
RUPPAER-SCHRANKEN,	Carniola, ...	1870.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
RUPPICHTERROTH, .	Sieg C., Rhenish Prussia, .	1869 + 1.	2
RUSSELHEIM, . . .	Darmstadt, ...	1869 + 7.	8
RUSSI, ...	Romagna, Italy, . . .	1870 + 7 ; 1881.	9
RUSSIA, Southern, . .	. . . . .	1821 + 2 ; 1838.	4
RUSSON, ...	Belgium, ...	1865.	1
RUSTCHUK = Roustchuk,	. . . . .		
RUVO, Terra di, . .	Basilicata, ...	1850 ; 1857.	2
RWONITZ, . . .	Saxon Voigtland, . .	1862.	1
RYDE, ...	Isle of Wight, . . .	1878.	1
SAALBAU, . . .	Rhine Valley, . . .	1869.	1
SAALFELD, . . .	Saxe Meiningen, . . .	1588.	1
SAANEN, ...	Vaud Canton, . . .	1874.	1
SAAS, ...	Valais, ...	1878.	1
SAAZ CIRCLE, . . .	Bohemia, ...	1784 ; 1811.	2
SABA DESERT, . .	Arabia, ...	742.	1
SABINA, ...	Roman States, . . .	1786.	1
SABINE COUNTRY, .	. . . . .	B.C. 177.	1
SABONY, ...	Caucasus, ...	1858.	1
SABRES, ...	Landes, ...	1854 + 1.	2
SABSERRA, . . .	Portugal, ...	1847.	1
SACHSEMB, . . near	Nordhausen, Thuringia, .	1863.	1
SACHSENBURG, . .	Carinthia, ...	1862 ; 1869 ; 1881.	3
SACILE, ...	Udine, North Italy, . .	1859 N.E.–S.W.	1
SACKIGEN, . . .	Baden, ...	1861 ; (1870 + 1) S.W.–N.E. ; 1879 + 1.	5
SACQUENAY, . . .	Côte d'Or, ...	1862.	1
SACRA DI S. MICHALE,	. . . . .	1871.	1
SADON, ...	Lat. 43° 52′ Long. 41° 41′ } Caucasus, .	1854 N.E.–S.W.	1
SADDLE ISLANDS, . .	Zabayer Islands, Red Sea, .	1846.	1
SAFFY, ...	Morocco, ...	1755.	1
SAGOR, ...	Carniola, ...	1852 + 1 ; 1864 + 2 ; 1879.	6
SAGORBE, . . .	Valencia, ...	1839.	1
SAHUT, ...	Anatolia, ...	1862, town destroyed	1
SAIFRITS = SAIFNITZ,	Carniola, ...	1855 W.–E. ; 1876 ; 1878 + 1 ; 1879 ; 1882.	6
SAILLANS, . . .	Drôme, ...	1835.	1
SAINT ADRESSE, . near	Hâvre, ...	(1855 + 3) N.–S.	4
SAINTES, ...	Charente Inférieure, . .	815 ; 840 ; 1852 ; 1856 ; 1874.	5

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ST. AGNES, . . .	Cornwall, ...	1859.	1
ST. AIGNAN, . . .	Côtes du Nord et Morbihan,	1870.	1
ST. ALBAN, . . .	Maurienne, Savoy, . .	1847.	1
ST. AMBROSE, . . near	Turin, ...	1839.	1
ST. ANDÉOL, . . .	Ardèche, ...	1773.	1
ST. ANDRÉ, . . .	Commune de Juaye-Mondaye, [Calvados,	1861 + 1.	2
ST. ANDRÉ, . . .	Namur, Flanders, . .	1848.	1
ST. AUBIN, . . .	Neuchatel Canton, . .	(1842 + 1) S.–N.	2
ST. AMANT, . . .	Puy de Dôme, . . .	1880 E.–W.	1
ST. AUNIS, . . .	Charente Inférieure, . .	1870 + 3.	4
ST. BÉAT, ...	Haute Garonne, . . .	1885.	1
ST. BERNARD CONVENT,	. . . . .	1823; 1851 E.–W. + 1; 1854 E.–W. + 1; 1855 + 1; 1858 + 1; 1868; 1881, and mountain.	11
ST. BERNARDIN, . .	Grisons, ...	1880 + 2.	3
ST. BETRAND DE COMMIGNES,	Haute Garonne, . .	*1835* E.S.E.–W.N.W. + 1, direction of beds of compact limestone of lower chalk, and of chain of Pyrénées.	2
ST. BLAISE, . . .	Neuchatel Canton, . .	1830; 1855 N.–S.; 1856 + 1.	4
ST. BRESSON VALLEY, .	Vosges, ...	1851.	1
ST. BRIEUX, . . .	Côtes du Nord, . . .	1826 + 1; 1851; 1853 + 1 W.–E.; 1868; 1877.	7
ST. CLOUD, . . .	Seine, ...	1769.	1
ST. COLOMBE, . .	Aude, ...	1837.	1
ST. CROIX, . . .	Vaud Canton, Switzerland, .	1846.	1
ST. CROIX, TOWN, . .	Morocco, ...	1731, violent; 1755.	2
ST. DENIS, . . .	Seine, ...	1316; 1862.	2
ST. DENIS D'ACLON, .	Normandy, ...	1878	1
ST. DENIS DU SIG, . .	Algeria, ...	1857 S.W.–N.E.; 1872.	2
ST. DIE, ...	Alsace, ...	(1829 + 3) N.–S.; 1831 S.W.–N.E.	5
ST. DIZIER, . . .	Doubs, ...	1857.	1
ST. FIRMIN, . . .	Saône et Loire, . . .	1871.	1
ST. FLUOR, . . .	Cantal, ...	1861 E.–W. + 2; (1862 + 1) W.–E.	5
ST. FOY L'ARGENTIÈRE, .	. . . . .	1841.	1
ST. FOY LES LYON, . .	. . . . .	1840.	1
ST. GALL, CANTON, .	. . . . .	1881.	1
ST. GALL, . . .	. . . . .	1533; 1720 + 1; 1816; 1826; 1827; 1835; 1851; 1852; 1877; 1880; 1881 + 8.	20
ST. GENIEZ, . . .	Aveyron, ...	1840; 1855; 1866.	3
ST. GERMAIN, . .	Saône et Loire, . . .	1871, the centre of the shock between the coal basins of Arroux, Bourbinée, Epinac, and Blanzy.	1
ST. GEORGES D'HURTIÈRE,	Maurienne, ...	1847.	1
ST. GEORGEN, . near	Presbourg, Hungary, . .	(1866 + 1) S.–N.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ST. GEORGEN, . .	Upper Austria, . . .	1785 + 4.	5
ST. GERVAIS, . . .	Haute Savoie, . . .	1817 ; 1854 + 1 ; 1857 + 3 ; 1868 ; 1881.	9
ST. GIRONS, . . .	Arriège, ...	1779 N.W.–S.E.	1
ST. GOAR, . . .	Rhenish Prussia, . . .	1619 ; 1786 ; 1845 ; 1869 S.–N. + 4 + 1 W.–E. + 1 S.E.–N.W.	10
ST. GOARHAUSEN, .	. . . . .	1846 + 5.	6
ST. GOTHARD Mountain,	. . . . .	1879.	1
ST. HYPPOLITE, . .	Doubs, ...	1843 S.E.–N.W.	1
ST. IMIER, . . .	Berne Canton, . . .	1853 ; 1854 ; 1868.	3
ST. IVAN ISLAND, . .	Hungary, ...	1879.	1
ST. IVAN ZELINA, . .	Agram, ...	1880 + 3 ; 1881 W.–E. + 31.	36
ST. IVES, ...	Cornwall, ...	1757 ; 1860.	2
ST. JEAN, . . .	Mayen C., Rhenish Prussia,	1869 + 1.	2
ST. JEAN D'ANGELY, .	Charente Inférieure, . .	1835 + 1.	2
ST. JEAN D'ACRE, . .	Syria, ...	*1836.*	1
ST. JEAN de Belleville, .	Savoie, ...	1865 + 1.	2
ST. JEAN de Boisseaux, .	Loire Inférieure, . .	(1826 + 1) S.–N.	2
ST. JEAN de Garguier, near	Marseilles, ...	1846 + 1.	2
ST. JEAN de Leone, .	Jura, ...	1783.	1
ST. JEAN de Luz, . .	. . . . .	1853 ; 1854 N.–S.	2
ST. JEAN de Maurienne, .	Savoie, ...	1808 ; 1811 + 1 ; 1838 + 1 ; (1839 + 49) N.W.–S.E. + 1 + 49 ; 1840 + 10 ; 1841 + 1 ; 1842 + 2 ; 1844 + 4 + 1 ; 1849 ; 1851 ; 1865 + 1 ; 1881.	132
ST. JEAN le Vieux, . .	Basses Pyrénées, . .	1858 + 9 ; 1859, violent.	11
ST. JEAN Pied du Port, .	,, ,, . .	1773 ; (1858 + 1) S.E.–N.W. + 4 ; 1860 ; 1864 ; 1866 W.–E.	10
ST. JEAN Pied Gauthier,	Maurienne, ...	1847.	1
ST. JÖRIS, . . .	Rhône Valley, . . .	1868.	1
ST. JULIEN en Genevois,	. . . . .	1881.	1
ST. JULIEN en Chassée, .	Oise, France, . . .	1756.	1
ST. JUST, ...	Cornwall, ...	1860.	1
ST. LAURENT, . .	Pyrénées Orientales, . .	1862.	1
ST. LAURENT, . .	Styria, ...	1865 + 1 ; 1873 E.–W.	3
ST. LAURENT les Bains,	Ardèche, ...	1845.	1
ST. LAURENT de Silanque,	Pyrénées Orientales, . .	1797.	1
ST. LAWRENCE, . .	South Coast, England, .	1878.	1
ST. LEONARD'S, . .	. . . . .	1878.	1
ST. LO, ...	Manche, ...	1775 ; 1853 ; 1876.	3
ST. LOUIS, . . .	Baden, ...	(1830 + 3) S.W.–N.E.	4
ST. MACLOU, . . near	Hâvre, ...	1833.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ST. MALO, . . near	Trieste, ...	1869.	1
ST. MALO, . . .	Ille et Vilaine, . . .	1671; 1773 N.W.–S.E.; (1804 + 1) N.E.–S.W.; 1843; 1845; 1847; 1853; 1877.	9
ST. MARIE, . . .	Pyrénées Orientales, . .	1784 + 1; 1791 + 1; 1862.	5
ST. MARTIN, . . .	Salzburg Alps, . . .	1787.	1
ST. MARTIN, . . .	Croatia, ...	1871 N.W.–S.E.	1
ST. MARTIN DE BELLEVILLE,	Savoie, ...	1855; 1865.	2
ST. MARTIN DE HINK, .	Landes, ...	1867 S.–N. + 1 N.–S.	2
ST. MAIXANT, . .	Deux Sèvres, . . .	1866 + 1.	2
ST. MAURE, . . near	Tours, ...	1657, R. = 6 miles.	1
ST. MAURICE, . . .	Switzerland, . . .	1880.	1
ST. MAURICE LE GERARD,	Poitou, ...	1781.	1
ST. MÉDARD, ...	Gironde, ...	1852.	1
ST. MICHAEL, . .	Carinthia, ...	1866; 1867.	2
ST. MICHAEL, . .	Savoie, ...	1882.	1
ST. MICHAEL, . .	Illyria, ...	1866.	1
ST. MICHAEL, . .	Salzburg, Styria, . .	1881.	1
ST. NICHOLAS, . .	Bavaria, ...	1858.	1
ST. NICHOLAS, . .	Valais, ...	1847 + 3; 1855 + 38, the shocks equal to if not greater than those of Viège, both in number and intensity, + 1; 1847; 1857 + 3; 1858; 1859; 1860 + 2; 1861; 1862 + 3 + 1 E.–W.; 1871 + 2; 1882.	64
ST. OEDENRODE, . .	Holland, ...	1843 + 3.	4
ST. OSWALD, . . .	Tyrol, ...	1862 + 2.	3
ST. OSWALD, . . over	Ibiswald, Upper Styria, .	1874.	1
ST. PALAIS, . . .	Basses Pyrénées, . .	1858 S.W.–N.E.	1
ST. PAUL, . . .	Haute Savoye, . . .	1852; 1854.	2
ST. PAUL, NEAR GRASSE,	Alpes Maritimes, . .	1854.	1
ST. PAUL, . . .	Austria, ...	1857.	1
ST. PÉ DE BIGORRE, .	Hautes Pyrénées, . .	1850; 1866.	2
ST. PÉRAY, . . .	Ardèche, ...	1873.	1
ST. PETER, IN AHRN, .	Tyrol, ...	1862 + 5 + 1 N.W.–S.E.	7
ST. PETER, . . .	Styria, ...	1877; 1880 S.–N.	2
ST. PETER, . . .	Sulmthal, Istria, . . .	1881.	1
ST. PETER, IN SCHAFIGNY,	Switzerland, . . .	1880.	1
ST. PETER, STATION, .	Illyria, ...	1874 S.–N. + 1 + 2 S.–N.; 1877.	5
ST. PETERSBURG, . .	. . . . .	1802; 1804; 1854.	3
ST. PIERRE D'ALBIGNY,	Savoie, ...	1866.	1
ST. PIERRE DE MELAGE,	. . . . .	1861.	1
ST. PIERRE SUR DIVES,	Calvados, ...	1881.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ST. PIERRE ISLAND, .	Greek Archipelago, . .	1771.	1
ST. PIERRE DE VARIENNES,	Côte d'Or, ...	1871 S.–N.	1
ST. PLAIS, . . .	Basses Pyrénées, . .	1869.	1
ST. POLTEN, . . .	Austria, ...	1750.	1
ST. QUENTIN, . . .	Aisne, ...	(1873 + 1) N.–S. + 2.	4
ST. RADEGUND, . .	Styria, ...	1865 S.W.–N.E.	1
ST. RAPHAEL, . .	Dauphiny, ...	*1773* + *6* + 10.	17
ST. REMBERT, EN BUGEY,	Ain, ...	(1841 + 2) E.–W.	3
ST. REMI, . . .	Bouches du Rhone, . .	1818.	1
ST. REMY, . . .	Puy de Dôme, . . .	1818 + 2.	3
ST. ROMAIN D'ORSE, .	Forez, ...	1877.	1
ST. ROMAIN, ...	Côte d'Or, ...	1871.	1
ST. SAUVEUR, . near	Barrège, Hautes Pyrénées, .	1854.	1
ST. SAUVEUR DE LA CÔTE,	Savoie, ...	1855.	1
ST. SAVIN, . . .	Vienne, ...	1773 + 3 ; *1775.*	5
ST. SAVIN, . . .	Pyrénées, ...	1854.	1
ST. SEINE, ...	Côte d'Or, ...	1862.	1
ST. SERVAN, . . .	Ille et Vilaine, . . .	1804 + 1.	2
ST. SEVER, . . .	Landes, ...	1854 + 1.	2
ST. SEVER, . . .	Calvados, ...	1878.	1
ST. SIGOLÈNE, . .	Allier, ...	(1859 + 1) E.–W.	2
ST. SIMON (CANTON), .	Aisne, ...	1873 + 1.	2
ST. SIMON (VILLAGE), near	Agram, Croatia, . . .	1880 + 5 ; 1881 + 1.	8
ST. SORLIN D'ARVES, .	Maurienne, . . .	(1839 + 49) W.–E. ; 1844.	51
ST. STEPHEN, . .	Styria, ...	1867.	1
ST. UBES = SETUBAL, .	Portugal, ...	**1761** ; 1819 + 3 ; 1858 + 1 + 2.	9
ST. VIET, . . . near	Klagenfurt, . . .	(1825 + 4) S.W.–N.E. ; 1857 E.–W. + 1 W.–E. ; 1880 S.W.–N.E.	8
ST. WENDEL, . . .	Rhenish Prussia, . .	1828.	1
SAKATALI, . . .	2° E. of Tiflis, Caucasus, .	1853 ; (1868 + 2) N.E.–S.W. ; 1880.	5
SALA, ...	Sweden, ...	1775.	1
SALA, ...	Sicily, ...	1844 + 1.	2
SALA, ...	Parma, ...	1765 ; *1824* + *1* ; 1835 ; 1836 + 1.	6
SALA, ...	Abruzzi, ...	1844 + 3 ; 1857 + 3 ; 1858 + 4.	13
SALA, ...	Principato Citra, . .	1824 + 1 ; 1825.	3
SALA, ...	Morea, ...	1821.	1
SALCITO, ...	Molise Province, . . .	1845.	1
SALDENHOFEN, . .	Styria, ...	1825.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SALÉ, ...	Morocco, ...	1755; 1757; 1773 E.S.E.–W.N.W.	3
SALERNO, . . .	. . . . .	1684; 1720; 1752; 1822 + 1; 1825; 1846; 1853 + 1; 1857 + 2; 1858 + 9; 1865; 1875; 1876 + 4.	29
SALFORD, . . .	. . . . .	1864.	1
SALINES, ...	. . . . .	1846.	1
SALINO, ...	Maurienne, ...	1847.	1
SALIES, ...	Orthez, Basses Pyrénées, .	1858.	1
SALINS, ...	Jura, ...	1863 + 3.	4
SALJANY, . . .	Persia, ...	1869 W.–E., violent, extended along the Araxes.	1
SALLANCHES, . . .	Haute Savoie, . . .	1863; 1868.	2
SALMANSDORF, . .	Lower Austria, . . .	1875.	1
SALMONA, . . .	Maltese Islands, . . .	1730; 1841; 1857 + 1; 1881.	5
SALONICA, ...	. . . . .	**1759 + 2** + 63; 1760 + 3; 1766; *1829* + 5; 1838; 1843 + 4; 1845; 1851 + 4 N.–S. + 3 N.–S.; 1855 + 3 + 1 E.–W.; 1856; 1857; 1858 + 1; 1869 N.E.–S.W. + 1 + 1 E.–W.; 1860 E.–W. + 4; 1861; 1864 + 6 E.–W. + 6 N.–S., extended along the coast to Gallipoli, + 3 E.–W.; 1865 + 1; 1866 N.–S.; 1867 + 4; 1868; 1869; 1870; 1871 S.W.–N.E. + 7 + 2 E.–W.; 1876; 1879 + 1.	150
SALCHLUF, . . .	Hesse Nassau, . . .	1870.	1
SALESBURG, . . .	. . . . .	1793.	1
SALORNAY SUR GREGIE, .	Saône et Loire, . . .	1871.	1
SALSA DI QUERZUOLA,	(Mud Volcano), Reggio Prov.,	1881 + 1.	2
SALTDALEN, . . .	Sweden, ...	1814 + 2; 1819 S.–W. + 3.	7
SALTEN, ...	Nordland Province, Norway,	1819.	1
SALUCES = SALUZZO, .	Piedmont, ...	1808 + 5; 1849; 1874, extended to Crissolo; 1878 E.–W.; 1882.	10
SALVAPIANA, . . .	Tuscany, ...	1824 + 25.	26
SALVINA, . . near	Adelsburg, Carinthia, . .	1834.	1
SALZACH, . . .	Solothorn Canton, . .	1846.	1
SALTZBURG, . . .	Tyrol, Austria, . . .	1667 + 3.	4
SALTZBURG DUCHY, .	Tyrol, ...	1862; 1873.	2
SALTZGITTEN, . .	Hanover, ...	1823.	1
SAMACHINSKY, . .	Caucasus, ...	1861 + 1; 1862.	3
SAMADEN, . . .	Grisons, ...	1871 + 2 S.–N.	3
SAMAKOF, . . .	20 km. S.E. of Sophia, .	1866.	1
SAMARKAND, . .	Turkestan, ...	1880.	1
SAMOBOR, . . .	12 miles West of Agram, .	1874 W.–E.	1
SAMOGYER COM., . .	Hungary, ...	1880 + 1 N.–S.; 1882 + 5.	8
SAMOS ISLAND, . .	. . . . .	*1831 + 1*; 1835; 1855 + 11; 1860 + 1; 1865 + 1; 1866; *1873 + 3*; 1880.	25

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SAMOTHRAKE, . .	Greek Archipelago, . .	1859 + 2.	3
SAMSOON, . . .	Black Sea, ...	1850 ; 1856 ; 1858 + 2.	5
SAN ALCACER, . .	Portugal, ...	1858.	1
SAN ANGELO dei Lombardi, ...		1852 ; 1853 + 20 ; 1856 ; *1857 + 5* ; 1858, felt at Potenza, and less strongly at Canossa ; 1869 + 1.	32
SAN ANTONIO, . .	Sicily, ...	1868.	1
SAN ARCHANGELO, .	Neapolitan Kingdom, . .	1857.	1
SAN BENIDETTO, . .	. . . . .	1870.	1
SAN BARTOLO, . .	Messina, ...	1881.	1
SAN CARLO, . . .	Anzesca Valley, Piedmont, .	1855 + 2.	3
SAND, ...	Tyrol, ...	1862 + 3.	4
SAN DAMIANO, . .	Piedmont, ...	1275.	1
SANDAZZO, . . .	Sicily, ...	1870.	1
SANDEC, ...	Galicia, Austria, . . .	1857 + 2.	3
SANDGRABEN, . .	Berne Canton, . . .	1828 + 4.	5
SANDOMIR, . . .	Poland, ...	1767.	1
SAN DONATO, . . .	Terra di Lavoro, . . .	1855 ; 1873 + 2.	4
SANDWICH, . . .	. . . . .	1691 ; 1776 ; 1848.	3
SANDWICK, . . .	Lewis, Scotland, . . .	1880.	1
SANET, ...	Alicante Province, . .	1854 + 2.	3
SAN GEMIGNANO, . .	Sienna, ...	1765 ; 1804 ; 1869 + 16.	19
SAN GERMANO, . .	Terra di Lavoro, . . .	1809 ; 1855 + 11 ; 1857.	14
SAN GIOVANNI Rotondo,	Capitanata, ...	1852.	1
SAN GIOVANNI, . .	Sicily, ...	1867 ; 1869 + 3.	5
SAN GIOVANNI, . near	San Martino Canavese, North [Italy,	1880.	1
SANGONERO, . . .	4 leagues W.S.W. from [Murcia,	1855 + 4.	5
SANGUINETTO, . .	Verona Province, . .	1841 + 7.	8
SANICANDRO, . . .	Capitanata, ...	1851 ; 1864 + 33 ; 1865.	36
SAN IPPOLITO, . .	Calabria Citra, . . .	1854.	1
SAN JUAN de las Abadesas,	Cataluña, ...	1852, in the carboniferous formation of, + 1.	2
SAN MARCO, . . .	Capitanata, ...	1875 + 2.	3
SAN MARINO, . . .	Principato, ...	1787.	1
SAN MICHELE in Bosco,	Romagna, ...	1881.	1
SAN MICHELE delle Chiese,	. . . . .	1866.	1
SAN MICHELE della Taverna,	Viterbo, . . .	1881 E.–W.	1
SAN NERO in Bagno, .	Tuscany, ...	1858 + 4, numerous.	5
SAN PAOLO, . . .	Capitanata, ...	1852.	1
SAN PEDRO del Pinadar,	Murcia, ...	1829.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SAN PHILIPE, . .	Valencia, ...	1747 ; 1803.	2
SAN PIETRO, . . .	Messina, Sicily, . . .	1786.	2
SAN PIETRO, . . .	Sardinia Island, . . .	1856 + 1.	1
SAN PIETRO, . . .	Brazza Island, Dalmatia, .	1881 S.W.–N.E.	1
SAN PIETRO, . . .	Treviso Province, . .	1859.	22
SAN PIETRO IN BAGNO, .	Tuscany, ...	1824 + 21.	1
SAN REGOLO, . . .	Tuscany, ...	1846 + 2.	3
SAN REMO, . . .	Genoa Coast, . . .	1818 ; 1831 + 3 ; 1851 + 1 ; 1855 + 1 + 1 N.W.–S.E. ; 1865 ; 1871 ; 1880.	13
SAN REMO, . . .	Piedmont, ...	1852 ; 1855 + 6 + 1 N.–S.	9
SAN ROQUE, . . .	Spain, ...	(1868 + 1) E.–W. ; (1869 + 1) E.–W.	4
SAN SEBASTIAN, . .	. . . . .	1660 ; 1854 N.–S. + 1.	3
SAN SEPOLCRO, . .	Arezzo Province, . .	1778 + 5 ; 1867.	7
SAN SEVERO, . .	Capitanata, ...	1828.	1
SAN SIMONE, . .	Terra di Otranto, . .	1881.	1
SAN STEFANO, . .	Turkey, ...	1865.	1
SAN STEFANO, . .	Calabria, ...	1870 ; 1871 + 6, extended from San Stefano to Amantia.	8
SANTANDER, . . .	Spain, ...	1817.	1
SANT ANGELO, . .	Abruzzo Citra, . . .	1845 ; 1857.	2
SANTA AGATHA FELTRIA,	Romagna, ...	1881.	1
STA. AGATHA DI TORTONA,	Tortona Province, . .	1858 W.–E. + 1.	2
STA. CROCE DI MORCONE,	Molise Province, . .	1853.	1
STA. CRUZ, . . .	Barbary, ...	*1761* + *1* + 2.	3
STA. DOMENICA, . .	Calabria, ...	1870.	1
STA. FÉ, ...	West of Grenada, . .	1790.	1
STA. LUCA, . . near	Bologna, ...	1881.	1
STA. LUCIA DI MILAZZO, .	Sicily, ...	*1823* + *3* ; 1867.	5
STA. MAGDALENA, .	Carinthia, ...	1856 + 1.	2
STA. MARGARITA, . .	Majorca Island, . . .	1863 + 2.	3
STA. MARGARETHEN, .	Carniola, ...	1871 + 4.	5
STA. MARGUERITA, .	Girgenti, ...	1766.	1
STA. MARIA, . . .	Terra di Lavoro, . . .	1694.	1
STA. MARIA PUERTO DE ANDALUCIA,	. . . .	1772 + 1 ; 1773.	3
STA. MARIA, . . .	Honth Com., Hungary, .	1866 N.–S. + 1.	2
STA. MARIA A MONTE, between Pisa and Florence,	. .	1853.	1
STA. MARIA DI NISCONI, .	Sicily, ...	1790 + 6, a certain area of ground sunk, and from fissures issued petroleum, sulphurous vapours, hot water, and finally a stream of salt mud.	7

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
STA. MAURA ISLAND, .	Grecian Archipelago, . .	1704 + 3 ; *1770* ; 1783 ; *1784* + 3 ; **1804** + 1 + 1 ; 1820 + 420 + **4** ; *1824* + 2 ; 1825 + 8 ; 1848 + 12 ; 1852 + 16 ; 1853 + 5 ; 1858 + *5* ; 1859 ; 1867 + 6 ; 1868 S.W.–N.E. ; 1869 + 4 1870 + 2.	509
SANTAREM, . . .	Portugal, ...	1857.	1
STA. SOFIA, . . .	Firenze, ...	1768.	1
STA. VENERINA, . .	Sicily, ...	1865 + 1 ; 1868 + 1 ; 1869 + 5 ; 1879 ; 1880 + 7 ;	19
SANTIAGO DE LA VEGA, .	. . . . .	1762 ; 1783.	2
SANTIAGO DE COMPOSTELLA,	Galicia, Spain, . . .	1783 ; 1858 S.W.–N.E. + 1 ; 1863 + 1 S.–N.	5
SAN TINDERO, . .	Sicily, ...	1786.	1
SANTO GEMINI, . .	Spoleto, ...	1752 + 3 ; 1753 + 1 ; 1783.	7
SANTO MAURO, . .	Calabria, ...	1832.	1
SANTORIN ISLAND, .	. . . . .	1507 ; 1647 ; 1649 + 3 ; *1650* + 4 + 1, subterraneous eruption ; 1672 ; 1707 + 3 ; 1708 + 3 ; 1837 ; 1843 ; 1856 + 1 + 1 W.–E. ; 1857 ; 1866 + 16 ; 1867 + 1 ; 1870 + 1.	48
SAN VITALE DI BAGANZA,	Near Parma, . . .	1834.	1
SAN VITTORE, . near	Bellinzone, Grisons, . .	1868 ; 1877 ; (1882 + 1) N.–S.	4
SANCT BLASIEN, . .	Schwartzwald, . . .	1879 + 2.	3
SANCT GEORGEN = GIURGIEVIC,	Croatia, . . .	1870 + 3 + 1 S.–N.	5
SANCT GEORGEN, . .	Upper Austria, . . .	1785.	1
SANCT GEORGEN, . .	Carinthia, ...	1880 S.W.–N.E.	1
SANCT GEORGEN, . .	Am Langsee, Carniola, .	1879.	1
SCT. GEORGE, . near	Pressburg, Hungary, . .	(1866 + 1) S.–N.	2
SCT. GOARTHAUSEN, .	Nsssau, ...	1869 + 3.	4
SCT. INGBERT, . .	Saarthale, Rhenish Prussia, .	1869 + 1.	2
SCT. JOHANN, . .	Wieselburg Com., Hungary,	(1882 + 1) S.–N.	2
SCT. JACOB, . . .	Tyrol, ...	1858 S.–N. ; 1862 S.–N. + 1 + 1 E.–W.	4
SCT. JACOB II., . near	Gurk, Carinthia, . . .	1860 ; 1870.	2
SCT. JOAN, . . .	Agram, ...	1880.	1
SCT. KANZIEN, . .	Carniola, ...	1871 + 4.	5
SCT. LAMBRECHT, .	Upper Styria, . . .	1878 + 5 + 1 N.W.–S.E. ; (1881 + 1) S.W.–N.E. + 1.	10
SCT. LEONARD, . .	Lavanthal, Carinthia, . .	1877 N.E.–S.W.	1
SCT. MORITZ, . . .	Engadine, ...	1881 + 1.	2
SCT. PETER, . . .	Grisons, ...	1880 + 1.	2
SCT. WENDEL, . .	Saarlouis C., Rh. Prussia, .	(1869 + 2) N.–S. + 1 + 1 E.–W.	5
SAÔNE ET LOIRE, DEPT.,	. . . . .	1851 ; 1881.	2
SAPARDJIA, . . .	Anatolia, ...	1878.	1
SAPHIT, ...	Syria, ...	**1836**, town utterly ruined ; 3500 out of 4000 persons perished.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SAPONERA, . . .	Basilicata, ...	**1857** + 8, the greatest destruction happened in a triangle formed by Montenarro, Saponera, Viggiano) + 2 ; 1858 + 1.	13
SAPRI, ...	Calabria Citra, . . .	1858 + 6.	7
SARA ISLAND, . .	Caspian Sea, . . .	1840 + 1.	2
SARAGOSSA = Zaragoza,	Spain, ...	1817.	1
SARCONI, ...	Basilicata, ...	1857.	1
SARDIT, ...	Caucasus, ...	1868 + 1.	2
SARDINIA ISLAND, .	. . . . .	1618.	1
SARDINIAN Coast and African Coast (between them),		1855, submarine.	1
SARGANS, . . .	St. Gall Canton, . . .	1842 + 3 ; 1852.	5
SARGUEMINES, . .	. . . . .	1798 ; 1846.	2
SARITCHABAN, . .	Rumili, Turkey, . . .	1863 + 1.	2
SARK ISLAND, . .	. . . . .	1843.	1
SARMEDE, . . .	Treviso Province, . .	1873 ; 1875.	2
SARPSBORG, . . .	Sweden, ...	1874 W.–E.	1
SARNEN, ...	Unterwalden Canton, . .	*1836 + 1.*	2
SARRE, ...	Basses Pyrénées, . . .	1853.	1
SARRANCE, . . near	Pau, ...	1807 + 4.	5
SARREBOURG, . .	Meurthe, ...	1668.	1
SARREBRÜCKEN, . .	. . . . .	1846 ; 1869 N.W.–S.E. + 2 N.–S. ; 1874.	5
SARRELOUIS, . . .	. . . . .	1691 ; 1846.	2
SARTEANO, . . .	Padua Territory, . . .	1861 + 1.	2
SARTENE CANTON, .	Corsica, ...	1827 + 1.	2
SARWAR, , . .	Pannonia, ...	A.D. 455.	1
SASCUT, ...	Roumania, ...	1880.	1
SASSANO, ...	Principato Citra, . . .	1857.	1
SASSO, ...	Basilicata, ...	1857.	1
SASSO, ...	Bologna, ...	1864.	1
SATALIN ISLAND, . .	Grecian Archipelago, . .	1688.	1
SAUGE, ...	Neuchatel Canton, . . .	(1842 + 1) S.–N.	2
SAULGAU, . . .	Würtemberg, . . .	(1830 + 2) W.–E.	3
SAUMUR, ...	Maine et Loire, . . .	1588 ; 1808 ; 1810 ; 1851 ; 1859.	5
SAUVETERRE, . .	Languedoc, . . .	1840.	1
SAUZILLAGES, . .	Puy de Dôme, . . .	1881.	1
SAVARESA, . . .	Italy, ...	1847.	1
SAVETHAL, Lower, .	. . . . .	1870 + 1.	2
SAVELLO, . . .	Calabria, ...	1853.	1
SAVENA, River Valley, .	Italy, ...	1881.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SAVENA, . . . near	Genoa, ...	1818 ; 1865 ; 1881 N.–S.	3
SAVIGLIANO, . . .	Piedmont, ...	1858 ; 1864 ; (1878 + 1) E.–W.	4
SAVIGNANO, . . .	Capitanata, ...	1853.	1
SAVIGNO, . . .	Bologna, ...	1864.	1
SAVIO Valley, . .	Romagno, ...	1881.	1
SAVOGNA, . . .	S.S.W. of Görtz, . .	1870.	1
SAVOLO, ...	Neapolitan Kingdom, . .	1854.	1
SAVOIE, La, . . .	. . . . .	1248 ; 1621 ; 1682 + 3 ; 1753 ; 1755 ; 1756 ; 1784 ; 1841 S.E.–N.W. + 2 ; *1844* + 1 ; 1854 ; 1857 ; 1877 ; 1881.	19
SAXONY, . . .	. . . . .	1590 ; 1701 ; 1764 + 1 ; 1770 ; 1832 + 2.	8
SAXONY, Upper, . .	. . . . .	823 ; 1821, extended to Krotendorf in the S., Eitsitch, near Leipzig, in the N., Mitweida, in the E., Etzdorf, in the W. The principal axis of the area shaken seems to have had the direction N.W.–S.E., at right angles to the chain of the Erzegebirge.	2
SAXON, ...	Valais, ...	1881 ; 1882.	2
SCALA NOVA, . . .	Anatolia, ...	1823 + 1.	2
SCALCA, ...	Calabria, ...	1780.	1
SCALLESSAIG, . .	Scotland, ...	1880.	1
SCALMA, ...	Illyria, ...	1870 + 1.	2
SCANDALE, . . .	Calabria, ...	1832.	1
SCANDINAVIA, . .	. . . . .	1866, limits—N. Bodœ and Skeleftea, E. Sœderham, S.E. Felsund, S. Langesund, S.W. Bergen, W. Shetland Island. The centre of shock at Christianiasund.	1
SCANDINAVIA, Southern,	. . . . .	1858.	1
SCANELLO, . . .	Northern Italy, . . .	1881.	1
SCANFS, ...	Grisons, ...	1857 ; 1859 + 1 ; 1861 W.–E. ; 1870 ; 1871 ; 1882 + 2.	9
SCARBOROUGH, . .	. . . . .	1738 ; 1863.	2
SCARPERIA, . . .	Firenze, ...	1864 + 12 ; 1865 + 1.	15
SCANS, ...	Engadine, ...	1859 + 1.	2
SCARPANTO ISLAND, .	. . . . .	1856 ; 1882.	2
SCHABKA Village, . .	Soroka District, Bessarabia,	1879, fathom wide fissures opened, and water ejected from them.	1
SCHAFFHAUSEN, . .	Berne Canton, . . .	**1652** ; 1667 + 3 ; 1692 ; 1750 ; 1817 ; 1826 ; 1851 ; 1856 ; 1858 ; 1880 + 1 ; 1881 + 4.	19
SCHAFFHAUSEN, . .	Würtemberg, . . .	*1771* + *1*, extended over an area of 60 leagues long × 40 leagues wide.	2
SCHANDAU. . . .	Saxony, ...	1862 ; 1872.	2
SCHARANS, . . .	Grisons, ...	1882 + 1.	2
SCHATTDORF, . .	. . . . .	1869 + 1.	2
SCHATTENBERG, . .	Styria, ...	1864 + 1.	2
SCHATTWALD, . .	Tyrol, ...	1882 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SCHAUENBOURG, . .	Bâle, ...	(1836 + 1) S.–N.	2
SCHEER, ...	Swabian Alps, . . .	1830.	1
SCHEIBBS, . . .	Lower Austria, . . .	1874 ; 1876 + 2, centre of shock.	4
SCHELKOWODSKAIA STANITZA, Caucasus, . . .		1848 + 2.	3
SCHELLETAU, . .	Moravia, ...	1876.	1
SCHEMACHA, . . .	Caucasus, ...	**1667** + 45, lasted three months ; 1670 + 11 + **4** ; 1828 + 4 ; 1829 + 20 ; 1848 + 19 ; 1856 + 2 ; 1857 + 3 ; 1858 + 2 ; 1859, violent, + 9, continued from 30th May to 18th June, most destructive, + 4 ; 1860 ; 1861 E.–W. + 7 + 2 E.–W. ; 1862 + 9 + 1 N.–S. ; 1863 + 1 + 1 N.E.–S.W. ; 1864 + 1 ; (1867 + 3) E.–W. + 1 ; 1868 + 2 ; 1869, extended over 5000 square versts ; magnets lost their attractive power, + 4 ; (1870 + 12) N.E.–S.W. ; 1871 ; *1872* + 2, town nearly destroyed, + 1, town destroyed completely, + 3 ; 1880, severe.	194
SCHEMNITZ, . . .	Saxony, ...	1855.	1
SCHEMNITZ, . . .	Hungary, ...	*1763* + *1* ; 1854 + 4 ; 1855 ; 1858 S.E.–N.W. ; 1862 + 1.	11
SCHERNDORF, . .	Würtemberg, . . .	1861.	1
SCHIATHOS ISLAND, .	Grecian Archipelago, . .	1867 + 2 ; 1869 + 2.	6
SCHIEDAM, . . .	Holland, ...	1803 ; 1804.	2
SCHIERSTEIN, . .	Rhine Valley, . . .	1869 + 1 + 1 N.–S.	3
SCHIRAZ, . . .	Persia, ...	1862 N.–S. + 10 ; (1863 + 3) N.–S., disastrous, + 5 ; *1824* + 12, part of the city swallowed up, + 3 ; 1825 ; **1853**, town utterly destroyed, + **20**, 12,000 people perished.	58
SCHLAGGENWALD, .	Bohemia, ...	1862.	1
SCHLEBUSH, . . .	Solingin C., Rh. Prussia, .	1869.	1
SCHLECHTINGEN, . .	Waldbrohl C., Rh. Prussia, .	1869 + 2.	3
SCHLESWIG, NORTHERN,	. . . . .	1882.	1
SCHLESWIG-HOLSTEIN,	. . . . .	*1841* + *1*.	2
SCHLETTERS, . . .	Tyrol, ...	1860 + 1.	2
SCHLETTSTADT, . .	Alsace, ...	1636 + 24 ; 1785 ; 1823.	27
SCHLOSS-NEUHAUS,	Carinthia, ...	1879 S.W.–N.E.	1
SCHLOSS-SCHONBERG, .	Würtemburg, Odenwald, .	1869 + 1 N.N.E.–S.S.W. + 1 ; 1873 + 7 + 1 S.W.–N.E. ; 1874.	13
SCHLOSS-VOIGTBERG, .	Saxon Voigtland, . .	(1862 + 1) S.S.E.–N.N.W. + 2 N.–S.	4
SCHLÖTAL, . . .	N.W. Bohemia, . . .	1857.	1
SCHMIDTEN, . . .	Saltzbourg, ...	1864 W.–E.	1
SCHMIEDEBERG, . .	Silesia, ...	1799.	1
SCHMIEDEFELD, . .	Meiningen, ...	1831.	1
SCHNEEBERG, . .	Saxony, ...	1701 + 1 ; (1862 + 1) S.W.–N.E.	4
SCHNEEBERG, , .	Fichtelgebirge, Bavaria, .	1832 ; 1861 ; 1862 ; 1872.	4
SCHNEEKOPPE, . .	Riesengebirge, Silesia, [Prussia,	1829 + 2.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SCHŒSOL, . . .	Austria, ...	1857 + 1 E.–W.	2
SCHOLLENBACH, . .	Odenwald, ...	1869 + 2.	3
SCHONBERG, . . .	Saxony, ...	1770 + 6 ; 1872 ; 1878.	9
SCHONBERG, . . .	Bavaria, ...	(1869 + 1) N.N.W.–S.S.E.	2
SCHÖNDORF, . . .	Silesian Prussia, . . .	1878.	1
SCHÖNEBECK, . .	Saxony, Prussia, . . .	1872 + 1.	2
SCHÖNSTEIN, . . .	Styria, ...	1837.	1
SCHÖOTEN, . . .	Antwerp Province, . .	1848.	1
SCHOPFHEIM, . .	Baden, ...	1859 + 1 ; 1870 ; 1876 N.–S. ; 1878 ; 1879 + 1.	7
SCHOSSENREUT, . .	Bohemia, . . .	1824.	1
SCHORNDORF, . .	Würtemberg, . . .	1861.	1
SCHOTTEN, . . .	Darmstadt, ...	1869.	1
SCHOTTWEIN, . .	Simmering Mountn., Austria,	1862 E.–W. ; 1870 S.E.–N.W. ; 1872.	3
SCHOUSCHA, Choucha, .	Georgia, ...	1828 + 22 ; 1853 ; 1860 ; 1861 + 2 ; 1862 + 1 ; 1868, extended to Surnabad, Tiflis, and Deleschan ; 1869 + 3 + 1.	35
SCHRAMBERG, . .	Baden, ...	1824.	1
SCHRAWINKA, . .	Austrian Poland, . . .	1840 + 2.	3
SCHRABEREISEN, . .	Swabia, ...	1786.	1
SCHRUNS, . . .	Voralberg, Tyrol, . .	1867 ; 1872 + 1.	3
SCHTSCHEDRINSK, .	Russia, ...	1869.	1
SCHULS, ...	Grisons, ...	1869 + 1 ; 1870 + 1 ; 1871 + 1 ; 1882.	7
SCHUSCHA = SHUSHA, .	. . . . .	*See* Choucha.	
SCHUMLA, . . .	Lower Danube, . . .	1875.	1
SCHUTT ISLAND, . .	Danube, ...	1877 + 2.	3
SCHWABENBERG, . near	Pesth, ...	1880 E.–W.	1
SCHWALBACH, . .	Langen, Nassau, . . .	1869.	1
SCHWANHEIM, . .	Rhine Valley, . . .	1869 + 4 ; 1871 + 4.	10
SCHWANOWITZ, . .	Between Brünn and Cracow,	1786 + 1.	2
SCHWARRENBACH, .	Valais, ...	1855.	1
SCHWARZWALDE, . .	*See* Black Forest, . . .	1863.	1
SCHWARTZENBACH, .	Carinthia, ...	1837 ; 1866 + 1 ; 1867.	4
SCHWARTZENBERG, .	Saxony, ...	1821.	1
SCHWARTZENBERG, near	Idria, ...	1870.	1
SCHWARTZENFELS, .	Cassel, ...	1869.	1
SCHWARTZENFELS, near	Bad Brückenau, Bavaria, .	1869.	1
SCHWARTZWALD, . .	Baden (*see* Black Forest), .	1879 S.W.–N.E., south-west part of ; 1881, south part of, + 2.	4
SCHWATZ JEIBECK, .	Rottemberg, Tyrol, . .	1859 ; 1865.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SCHWECHWITZ, . .	Moravia, ...	1786.	1
SCHWEIDNITZ, . .	Silesia, Prussia, . . .	1799.	1
SCHWYTZ Canton, . .	. . . . .	1755; 1852; 1879; 1881.	4
SCHWITZ, . . .	. . . . .	1850; 1851 + 2; 1855 + 1; 1856 + 1; 1877.	9
SCIACCA, ...	Sicily, ...	1578; 1652; 1724; 1726 + 3; 1740 + 104; 1816 + 3; 1831 + 6; 1832; 1846.	125
SCILLY ISLAND, . .	. . . . .	1757; 1771; 1847.	3
SCIO ISLAND, . . .	. . . . .	1767; 1850.	2
SKOPELOS ISLAND, .	Greece, ...	1867.	1
SCOTLAND, . . .	. . . . .	1019; 1872, violent, + 1.	3
,, Northern, .	. . . . .	1846; 1869 + 1.	3
,, Southern, .	. . . . .	1786.	1
,, Western, .	. . . . .	132; 1732.	2
,, Two-thirds of,	. . . . .	1839, the southern limit coincided with a line drawn from the Solway to the mouth of the Tweed, and the northern limit as nearly coincided with the course of the Caledonian Canal.	1
SCUTARI, ...	Albania, ...	1829 + 1; 1855 E.–W. + 93 + 3 N.E.–S.W.; 1862; 1864 S.–N. + 2 N.–S.	103
SCUTSCHACH, . . .	Clagenfurt, ...	1830.	1
SCYROS ISLAND, . .	Sporades, ...	1853 + 2.	3
SEAVINGTON, . . .	. . . . .	1868.	1
SEBASTOPOL, . . .	Crimea, ...	1855 N.–S.; 1869; 1875, violent.	3
SEBENCIO, . . .	Dalmatia, ...	(1881 + 1) S.W.–N.E.	2
SECHTEM, . . .	Bonn Canton, Rh. Prussia, .	1856; 1869 + 2.	4
SEDAN, ...	. . . . .	1755 + 1; 1756; 1767.	4
SEEBERG, . . .	Solothorn Canton, . . .	1837 + 1.	2
SEEBSAGUIR, . . .	Upper Austria, . . .	1842 S.W.–N.E.	1
SEEDORF, . . .	. . . . .	1869 + 1.	2
SEEFELD, . . .	Tyrol, ...	1878 + 1; 1880 W.–E.	3
SEEGRABEN, . . .	N.E. of Lœben, Styria, .	1867.	1
SEEHEIM, . . .	Rhine Valley, . . .	1869.	1
SEGRÉ, ...	Maine et Loire, . . .	1775.	1
SEICHES, ...	Maine et Loire, . . .	1841 E.–W.	1
SEIDENBERG, . . near	Bad Landeck, Silesia, . .	1878.	1
SEINE Inferieure, Depmt.,	Coast of, ...	1848.	1
SELB, ...	Upper Saxony, . . .	1780, continuous, + 8; (1783 + 6) S.–W. + 3.	19
SELBY, ...	. . . . .	1704.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SELENGINSK,	91 versts from Irkutsch, Siberia,	1771 + 1; 1803; 1811; 1815; 1818; 1829; 1839; 1847; (1848 + 1) W.–E.; (1849 + 1) N.–S.; 1850 W.–E. + 1 + 1 N.W.–S.E.; (1851 + 1) N.–S. + 1 N.W.–S.E.; 1852 + 1; 1853; 1854; 1855 N.–S. + 2 N.W.–S.E.; 1856 N.W.–S.E. + 5 N.–S. + 3 + 1 N.W.–S.E.; 1857 1 + 2 N.W.–S.E.; 1860; 1862 + 96 + 10 N.–S. + 1 N.–S., violent, + 1 N.E.–S.W.; 1864 + 4 N.–S.; (1865 + 1) N.–S. + 3; 1867 + 3, of 26 shocks recorded by Mr. Kehlberg from 23rd Aug., 1847, the directions were N.–S. on 7 occasions, N.W.–S.E. on 7 occasions.	164
SELIGENSTADT,	Darmstadt,	1869 + 2.	3
SELJE,	Norway,	1870.	1
SELLANO,	Spoleto,	1849 + 20 S.W.–N.E.	21
SELLIÈRES,	Jura,	1849.	1
SELOMMES,	Loire et Cher,	1864.	1
SELONGEY,	Côte d'Or,	1862 N.–S.	1
SELVA,	Majorca Island,	1721.	1
SEM,	Ariège,	1852.	1
SEMETINA,	Albania,	1866 + 4.	5
SEMIPALATINSK,	Russia,	1848 S.–N.	1
SEMLIN,		1773 + 2; 1798; 1801 + 2; 1802; 1808 + 2.	11
SENERCHIA,	Principato Citra,	1853.	1
SENHEIM,	On the Moselle,	1869 + 1.	2
SENIO Valley,	Romagna,	1879 + 6.	7
SENITZA,	Bosnia,	1868 + 3.	4
SENS,	Yonne,	1756.	1
SEO DE URGEL,	Cataluña,	1862.	1
SERAJEVO = Bosnia Seral,		1869 + 3 E.–W.; 1879 S.–N.; 1880; 1881; 1882 W.–E.	8
SERAVEZZA,	Lucca, Italy,	1847.	1
SERBIA,		1881.	1
SERÉS,	Asia Minor,	1868.	1
SERIANA Village,	Southern Algeria,	1869 + 1.	2
SERIANA Valley,	Northern Italy,	1882.	1
SERINE,	Capitanata,	1720.	1
SERNAGLIA,	Treviso Province,	1859.	1
SERNEUS,	Grisons,	1882 + 2.	3
SERON,	Andalucia,	1863 + 3.	4
SERRATA,	Calabria,	1869.	1
SERRA CAPRIOLA,	Capitanata,	1828; 1846; 1851; 1853 + 1 N.–S.	5
SERRA VALLE,	Treviso Province,	1859.	1
SERVE,	Neapolitan Kingdom,	1853.	1
SESSA,	Terra di Lavoro,	1856 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SESSANA,	Göritz, Austria,	1870 N.E.–S.W. + 1 ; 1872 N.E.–S.W. + 1 ; 1882.	5
SESSENBERG,	Austria,	1875 ; (1879 + 1) N.–S.	3
SESTO CALENDE,	Milano,	1851.	1
SETIF,	Algeria,	1855 ; 1856 + 16 ; 1862 N.–S. ; 1863 ; 1867 + 1 S.–N. ; 1869.	23
SETTEFRATI,	Terra di Lavoro,	1855 ; 1873 + 1.	3
SETTERSDORF,	Carinthia,	(1857 + 3) S.E.–N.W.	4
SETUBAL = ST. UBES,	Portugal,	*See* St. Ubes.	
SEURRE,	Côte d'Or,	1783.	1
SEVERAC,	Aveyron,	1876.	1
SEVERM, near	Carlstadt, Croatia,	1880 + 5.	6
SEVILLE,		1356 ; 1357 ; 1504 ; 1732 + 1 ; *1841* + 5 ; 1847 ; 1856 + 1 S.–N. ; (1858 + 2) E.–W. ; 1860.	18
SEVRES,		(1841 + 2) W.–E. ; 1853 + 1.	5
SEXTEN,	Tyrol,	1848 ; 1858.	2
SEYSSEL,	Ain,	1841 + 2.	3
SEZIMBRA,	Portugal,	1756 + 3.	4
SHAFTESBURY,		1761 ; 1762 ; 1793.	3
SHEARNESS,		1692.	1
SHEFFIELD PARK,	Sussex,	1864.	1
SHEFFIELD,		1795 ; 1816.	1
SHERBOURNE,		1761 ; 1868.	2
SHERWOOD,		1868.	1
SHESHADER,	Scotland,	1880.	1
SHETLAND ISLAND,		1866, extended to all the north of the Archipelago.	1
SHIRWAN,	Kurdestan, Turkey in Asia,	1859 ; 1871 + 2, very violent, town destroyed.	3
SHOREHAM,		1734.	1
SHREWSBURY,		1110 ; 1838 ; 1839.	3
SHROPSHIRE,		1712 ; 1836.	2
SHUPPANEEK,	Bannat,	1790.	1
SICHEM,	Palestine,	1546.	1
SICILY,		A. D. 34 ; 131 ; 795 ; 1086 ; 1100 ; *1155*, 5000 lives lost ; 1159 ; 1169 ; 1170 ; 1186 ; 1204 ; 1537 ; 1542, violent ; 1631 ; 1638 + 2 ; 1643 ; 1667 : 1692 ; **1693 + 1** ; 1694 ; 1696 ; **1706 + 1** ; 1711 ; **1726** ; 1727 ; 1744 ; 1751 ; 1754 ; *1756 + 1* ; 1770 ; 1777 ; 1780 + 3 ; 1783 ; 1786 ; 1791 ; 1805 ; 1811 ; 1813 ; 1814 + 1 ; 1816 ; 1817 + 1 ; 1819 ; 1822 + 3 ; 1823 ; 1831, town of Melazzo ruined, + 2 ; 1841 + 2 ; 1845 ; 1846 + 1 ; 1848 + 1 ; 1851 ; 1856 + 1 ; 1866 + 3 ; 1876 ; 1877, extended through Rome to Piedmont.	77
SICILY, NORTHERN PART OF,		1736.	1
,, WEST COAST OF,		1841.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SICILY, East Coast of, .	. . . . .	1726 ; 1878.	2
SIDI BEL ABBÈS, . .	Algeria, ...	1872 ; 1875.	2
SIDI FERRUCH, . .	Algeria, ...	1865.	1
SIDI OBKA, . . near	Biskra, Southern Algeria, .	1869 + 1.	2
SIEBENBURGEN, . .	Transylvania, . . .	1880 + 1.	2
SIEBENGEBIRGE MTS.,	. . . . .	1812 + 1 ; 1856.	3
SIEBENLEHEN, . near	Nossen, Saxony, . . .	1784.	1
SIEBERG, ...	Solothorn Canton, . .	1837.	1
SIEBITZ, ...	Bohemia, ...	1880.	1
SIEBURG, . . near	Bonn, Rhenish Prussia, .	1828 + 2 ; 1846 ; 1869 N.W.–S.E., R. = 11·4 miles, + 5.	10
SIEGHARTSKIRCHEN, .	Vienna, ...	1873 ; 1875.	2
SIMONSWALD, . .	Schwartzwald, . . .	1879.	1
SIENNA, ...	. . . . .	1320 ; 1361, violent, + 24 ; 1413 + 2 ; 1420, very violent ; 1430, very violent ; 1436, very violent ; 1456 ; 1459 + 1 ; **1461** + 3 ; **1467** + 3 + 20 (lasted 20 days) ; 1474 + 5 ; 1486 + 2 ; 1493 ; **1496** + **1** ; **1558** ; **1602** + **2** ; *1638* + 7 ; 1676 + 2 ; 1678 ; 1691 ; 1697 + 84 ; 1700 ; 1701 ; 1724 + 3 ; **1726** + **2** ; *1729* + 3 ; *1741* + 19 ; 1752 + 2 ; 1770 ; 1777 ; 1779 ; 1780 ; 1783 ; 1787 ; 1792 ; 1798 + 23 ; *1804* + **1** ; 1810 + 1 ; (1821 + 27) W.–E. + 5 ; 1823 ; 1824 ; 1825 + 2 ; 1843 + 3 ; 1847 + 22 1848 + 20 + 1 E.–W. ; 1849 + 2 ; 1850 N.–S. + 2 + 1 E.–W. ; (1851 + 1) S.S.W.–N.N.E. + 1 + 1 S.S.W.–N.N.E. + 1 S.–N. + 1 E.–W. ; 1853 E.–W. + 1 ; 1854 + 7 + 2 E.–W. ; 1855 + 2 ; 1856 ; 1857 ; 1858 ; 1859 + 52, centre at Sienna, extended over an elliptical area 16 miles to the W.N.W., 12 miles to the E.S.E. × 4 miles ; 1860 + 9 N.–S., marked magnetic derangements before shocks ; 1862 + 1 ; 1865 + 1 ; 1866 N.E.–S.W ; 1867 ; 1868 W.–E. + 1 ; 1869 + 1 + 14 + 1 W.–E. ; 1870 + 2 ; 1871 + 4 ; 1882 + 73, the zone of greatest intensity N.–S. through Sienna, 15 km. long and 8 km. broad.	536
SIEN, ...	St. Wenden C., Rh. Prussia,	1869 + 1.	2
SIENNA SOLFATARA, .	Near Velletri, . . .	1871.	1
SIERRA AMALGRERA, .	Spain, ...	1863.	1
SIERRE = SIDERS, . .	Valais, ...	1853 ; 1855 + 5 ; 1881 ; 1882 E.–W.	9
SIG, ...	Algeria, ...	(1873 + 1) E.–W.	2
SIGLITZ, ...	Saltzbourg Canton, . .	1845 + 4.	5
SIGMARINGEN, . .	Hohenzollern, Prussia, .	1805 ; 1855 + 2.	4
SIGNAFRH, . . .	Caucasus, ...	1853.	1
SIGU, ...	Dalmatian Coast, . .	1876 + 3.	4
SILA, ...	Calabria, ...	1870, centre of shock at Sila, extended along the line marked by Cellara, San-Stephano, Longobuco, and Rossano, and on both sides of this line which runs S.W.–N.E. reached Amantea ; 1871.	2
SILBERGRUN, . . .	Bohemia, ...	1824.	1
SILESIA, ...	. . . . .	1433 ; 1443 ; 1590 ; 1756 ; 1785 ; 1786 + 2 ; 1799 ; 1840 + 1 ; 1858 ; 1878 ; 1864 S.E.–N.W.	14

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SILISTRIA,	Bulgaria,	1880 + 20.	21
SILLEIN = ZSALNA,	Hungary,	1848 + 1 E.–W. ; 1853 ; 1858 + 105.	109
SILLIAN,	Tyrol,	1848 + 1 ; 1862 + 6.	9
SILLOTH,	Cumberland,	1871.	1
SILLY,	Meurthe,	1846.	1
SILS,	Tessin,	1861 ; 1862 ; 1869 S.E.–N.W. ; 1871 W.–E. + 1.	5
SILSDEN,	York,	1864.	1
SILVAPLANA,	Upper Engadine,	1852 + 3 ; 1861 ; (1882 + 1) N.E.–S.W.	7
SIMI ISLAND,	Anatolian Coast,	1863 + 1 ; 1868 + 5 ; 1869 + 10.	19
SIMACHKINKAYA,	Caucasus,	1861 + 1.	2
SIMEGH COM.,	Hungary,	1836.	1
SIMMERN,	Brandenburg, Prussia,	1869 + 2.	3
SIMPLON Mountain and	Hospital,	1850 + 1 ; 1863 ; 1869.	4
SINALUNGA,		1861.	1
SINDLINGEN,	Nassau,	1828.	1
SINES,	Portugal,	1858.	1
SINFALCO,	Calabria,	1626 + 1.	2
SINIGAGLIA,		1719 ; 1781 ; 1827 ; 1828 ; 1838 ; 1853 ; 1870.	7
SINZING,	Bavaria,	1861 N.–S. ; 1869 S.–N. + 1 ; 1878.	4
SION = SITTEN,	Haut Valais,	1716 + 3 ; 1802 + 3 ; *1803* + 3 ; 1837 + 1 ; 1839 + 1 ; 1842 ; 1851 + 1 ; 1853 + 4 S.E.–N.W ; (1854 + 1) N.–S. ; 1855 E.–W. + 13 ; 1856 + 1 ; 1858 + 2 E.–W. ; 1867 ; 1868 ; 1871 + 1 ; 1875 ; 1877 + 1 ; 1879 + 1 ; 1880 + 2 ; (1881 + 2) S.W.–N.E.	60
SIORAC,	Dordogne,	1847.	1
SIPPENAKEN,	Liège, Belgium,	1873.	1
SISSEK,	Austria,	1877.	1
SISTERON,	Basses, Alpes,	1708 ; *1802* + 1.	3
SISTERON, Arondissement,	Var,	1868.	1
SITTARD,	Limbourg, Netherlands,	1756.	1
SITTEN,	Switzerland,	*See* Sils.	
SKALHOLT,	Iceland,	1789 + 5.	6
SKAPTARFIAL,	Iceland,	1783 + *3*, the river Skapta disappeared completely, and a new Island rose from the sea.	4
SKARA,	W. Gothland, Sweden,	1775 ; 1874.	2
SKELLEFTEA,	Westerbothen, Sweden,	1866.	1
SKERRYRORE,		1880.	1
SKIEN,	Norway,	1834.	1
SKIPTON,	York,	1861.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SKOTZAU = SKOTSCHAU,	Silesia, Austria, . . .	1785.	1
SKRAWINKA, . . .	Austrian Poland, . .	1840.	1
SLANO, ...	Dalmatia, ...	1843 ; 1844 ; 1876 + 3 ; 1880 N.–S. ; 1881.	8
SLATENEGG, . . .	3 miles E. of Rudolfswerth, [Illyria,	1870.	1
SLATO = SLASKOW, .	Ural, ...	*1836* N.E.–S.W.	1
SLATOUST, . . .	Astrakan, ...	1836 ; 1837.	2
SLIS-MARIA, . . .	Grisons, ...	1864 + 2.	2
SMALA, LA, . . .	Algeria, . . .	1858 + 3.	4
SMEDLEY, . . .	. . . . .	1869.	1
SMERCAN, . . .	Hungary, ...	1786.	1
SMOLA, ...	Galicia, . . .	1871.	1
SMYRNA, ...	. . . . .	A.D. 160 ; 176 ; 1040 ; 1626 ; 1639 ; **1653**, very violent—2000 to 3000 people perished ; 1654 ; 1667 + 1 ; 1685 ; 1687 ; 1688 + 12 ; 1690 ; 1717 ; 1719 + 4 ; 1737 ; 1739 N.–S. + 4 ; 1745 + 19 ; **1754**, very violent ; 1766 ; 1771 ; *1778* + **1** + 62, followed by the plague, + *14* ; 1779 ; 1785 + 1 ; 1786 ; 1817 + 2 ; 1825 ; 1828 N.–S. + 1 ; (1829 + 1) N.–S. ; (*1836* + *4*) N.–S. ; 1839 ; 1840 + 1 ; 1841 ; 1843 + 1 ; 1844 ; 1845 + 13 ; 1846 + 9 + 1, R. = 20 leagues, + **1** N.W.–S.E. + 3 ; 1847 + 2 ; 1849 + 7 ; 1850 (from 5th to 17th April, shocks hourly), + 288 + 1 N.W.–S.E. + 17 ; 1851 + 9 ; 1852 + 1 N.W.–S.E. + 2, extended to Chesme Island, Anatolia ; 1853 + 1 ; 1854 ; 1855 + 8 + 3 N.–S. + 2 E.–W. ; 1856 + 14 + 2 S.–N. + 3 N.E.–S.W. ; 1857 S.W.–N.E. + 12 + 1 E.–W. ; 1858 N.–S. + 10 + 3 E.–W. ; 1859 N.E.–S.W. + 2 + 2 E.–W. ; 1860 N.N.E.–S.S.W., extended 5 leagues to N. and 7 leagues in the other direction, + **2**, extended to Pergamos N. 18 leagues, Aidin S. 24 leagues, Kassalia E. 9 leagues, Karabournou W. 14 leagues, + 1 E.–W., principally in the Valley of the Meander, + 3 + 1 E.–W. ; 1861 S.W.–N.E. + 6 + 4 E.–W. + 5 N.E.–S.W. + 1 N.–S. ; 1862 + 3 + 1 E.–W. + 1 N.E.–S.W. + 5 N.–S. + 2 N.N.E.–S.S.W. ; 1863 N.E.–S.W. + 7 + 6 E.–W. ; 1865 + 7 + 2 S.–N. ; 1866 S.W.–N.W. + 2 + 2 N.–S. ; 1867 N.W.–S.E. + 12 + 1 N.–S. ; 1869 + 1 + 1 N.–S. + 1 S.S.E.–N.N.W. ; 1870 + 3 ; 1871 + 2 + 1 W.–E. ; 1872 ; 1875 + 3 ; 1880 + 3, caused fissures and issues of water on the Smyrna Cassaba Railway line, + 27 ; 1881 N.E.–S.W. ; 1882 + 1.	721
SNAASEN, . . .	Norway, ...	1834.	1
SNEUM, ...	11 miles N. of Ribe, Denmark,	1873.	1
SOBARSIN, . . .	Hungary, ...	1861.	1
SOBERNHEIM, . .	Rhenish Prussia, . . .	1869.	1
SOCLE, ...	. . . . .	1855 W.–E.	1
SODERSCHITZ, . .	Carniola, ...	1869.	1
SŒBYE, ...	Æro Island, Denmark, .	1785 + 3.	4
SŒDERHANEN, . .	Gefleborg, Sweden, . .	1875 N.W.–S.E.	1
SŒDERMANLAND, . .	Lœn, Sweden, . .	1812 + 1 ; 1879 S.E.–N.W.	2
SOELLŒ = SELLŒ, . .	Christiansund, Norway, .	1845 N.–S.	1
SŒST, ...	Westphalia, Prussia, . .	1856 ; 1878.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SOFIA = SOPHIA, . .	Bulgaria, ...	1858, very violent, + 21 + (10 + 7) S.W.–N.E. + 17, precisely along the line traversed by the warm waters of the baths of Sophia; (1859 + 3) S.W.–N.E. + 2, violent; 1866.	63
SOGLIO, ...	Grisons, ...	1861 + 2.	3
SOISSONS, . . .	. . . . .	582; 1087; 1466 + 2.	5
SOKALOWBERG, . .	Volga River, near Saratow, .	1869.	1
SOLA, ...	Roman States, . . .	1777.	1
SOLEURS, . . .	. . . . .	1357; 1828; 1830; 1832; 1834 + 3; 1836 S.–N. + 1; 1837 + 1 + 8; 1845 + 1; 1850; 1851; 1852; 1853; 1855 + 2; 1856 + 2; 1857; 1869 + 2; 1878; 1880; (1881 + 3) S.–N.	42
SOLEURS CANTON = SOLOTHON CANTON . . .		1877.	1
SOLIGNAC, . . .	Haute Vienne, . . .	1854.	1
SÖLINGEN, . . .	Brandenburg, Prussia, .	1877; 1880.	2
SOLLINS, . . .	Calvados, ...	1837.	1
SOLMS-LAUBACH, . .	Darmstadt, ...	1788 + 3.	4
SOLOPUCA, . . .	Calabria Ultra, . . .	1853 + 1.	2
SOMAKI, ...	Armenia, ...	1880 + 1.	2
SOMERSETSHIRE, . .	. . . . .	103, a city swallowed up); 534; 1199; 1248, many churches injured; 1680; 1752; 1868.	7
SÖMMERING MOUNTAIN, .	Styria, ...	1851; 1865.	2
SOMOGY, COM., . .	Hungary, ...	1880.	1
SÖNDMÖR, . . .	Norway, ...	1766 + 1; 1767 + 2; 1771 S.E.–N.W. + 3; 1773 + 2. 1834.	13
SONDRIO, . . .	Italy, ...	1851; 1852; 1882 W.–E.	3
SONZINO = SONCINO, .	Oligio Valley, Northern Italy,	1802.	1
SORA, ...	Terra di Lavoro, . . .	1770 + 2; 1840 + 3; 1857; 1871 + 1; 1874.	11
SORAU, ...	Silesia, ...	1785.	1
SORIANA, . . near	Biskra, Southern Algeria, .	1869 + 1.	2
SORIANO, . . .	Calabria, ...	1869.	1
SOROKI, ...	Wilna, S.W. Russia, . .	1866.	1
SORRENTO, . . .	. . . . .	1694; 1851 S.E.–N.W.	2
SOSPELLO, . . .	Nice, ...	1771.	1
SOUDAQUE, . . .	Crimea, ...	1869.	1
SOULAGES, . . .	Ruines Canton, Cantal, .	1861 N.W.–S.E.	1
SOULI, ...	Turkey, ...	1823.	1
SOULTZ, ...	Würtemberg, . . .	1818; 1848 N.N.W.–S.S.E.	2
SOULTZBACH, . .	. . . . .	1851, very violent.	1
SOULU, . . . near	St. Hyppolite, Doubs, . .	1843.	1
SOUND OF MULL, . .	. . . . .	1880.	1
SOUNENBERG, . .	Rhine Valley, . . .	1868.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SOURNABAD,	*See* Zournabad.		
SOUTH DALTON,		1704.	1
SOUTHAMPTON,		1750; 1834; 1853; 1878.	4
SOUTHWELL,		1792.	1
SOWERBY BRIDGE,		1869.	1
SPA,	Liège, Belgium,	1828; (1867 + 3) N.W.–S.E.	5
SPAICHINGEN,	Würtemberg,	1851; 1855 + 1.	3
SPAIN,		1081; 1157; 1293; 1356 + 3; 1427 + 4; 1531; 1580; 1660; 1661; 1680 + 3; **1755**, great Lisbon earthquake, + 1 (except Cataluña); 1803.	23
,, Western half of,		1858.	1
,, Southern Coast of,		1773 + 3.	4
,, Central,		1817; 1841 + 1.	3
,, Part between the two Seas from Santander to Tarragona,		1817.	1
SPALATRO,	Dalmatia,	1836 S.E.–N.W.; 1843; (1856 + 1) S.E.–N.W.; 1870; 1873; 1882 S.–N.	7
SPARTA,		B.C. 469; A.D. 1842; 1863 + 3; 1867 S.–N. + 2.	9
SPELLO,	Perugia, Italy,	1832.	1
SPEREMBERG CASTLE,	Westphalia,	1612.	1
SPERLINGA,	Sicily,	1822.	1
SPEZZANO,	Albanese,	1856.	1
SPEZZIA,		1777; 1852; 1855; 1860; 1874.	5
SPEZIA ISLAND,	Grecian Archipelago,	1837.	1
SPIDERBERG,	Norway,	1785.	1
SPIELFELD,	Styria,	(1880 + 1) S.W.–N.E.	2
SPIEZ,	Berne Canton,	1729.	1
SPINAZZOLA,	Terra di Barri,	1851; 1860.	2
SPINEA DI MESTRE,	Venetia,	1881.	1
SPINOSA,	Basilicata,	1857; 1858.	2
SPIRES,	Bavaria,	838; 1570 + 3; 1642 + 3; 1776 + 1; *1784 + 1*; 1822; 1869; 1880.	16
SPITTAL-ON-DRAVE,	Carinthia,	1857 S.W.–N.E. + 3; 1879 + 2; (1881 + 3) E.–W.	11
SPLUGEN,	Grisons,	1859; 1861; 1863; 1865; 1871; 1880 S.–N. + 2.	8
SPOLETO,		1298; 1703 + 1; 1704 + *1*; 1719; 1752; 1756; 1765 + 3; 1767 + 8; 1785 + 1; 1786, and all the plain between Terni and the foot of the Apennines; 1791 + 23; *1804* + 7; 1838 + 1; 1866 + 5; 1870; 1871 + 4; 1873; 1880 + 1; 1881 + 2 + 2 N.E.–S.W.; 1882 N.E.–S.W. + 4.	83
SPORADES ISLAND,		1864; 1865.	2
SPRENDLINGEN,	Darmstadt,	1869 + 2.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SQUILLACE, . . .	Calabria, ...	1870.	1
STAEFA, ...	Switzerland, . . .	1861 E.–W.	1
STÄFFIS = ESTAVAYER,	Fribourg, ...	1855.	1
STAFFORDSHIRE, . .	. . . . .	1678.	1
STAFFUANGER = STAVANGER, Norway, .	. . . .	1751 ; 1752 + 4 ; 1788 ; 1834 ; 1863.	9
STAGNO PICCOLO, . .	Dalmatia, ...	1850, very violent, + 138 ; 1851 + 54 + 4 N.–S. + 12 ; 1852 ; 1853 ; 1854 ; 1880 N.–S. ; 1881 + 2.	217
STALDEN, . . .	Valais, ...	1855 + 49 ; 1858 + 1 ; 1860 ; 1861 ; 1862.	55
STALDENRIED, . .	Valais, ...	1855 ; 1860.	2
STALLA, ...	Switzerland, . . .	1862 N.W.–S.E.	1
STAMFORD, . . .	. . . . .	1755 ; 1792 ; 1813 ; 1837 ; 1844.	5
STANCHO ISLAND = Cos	Is. = Ko, Ægean Sea, . .	1672 ; 1856 ; 1863 + 2.	5
STAND, ...	. . . . .	1869.	1
STANIMAKA, . . .	Rumili, ...	1880 + 1.	2
STANTON, . . .	. . . . .	1666.	1
STANZ, ...	Styria, ...	1857 + 1.	2
STANZ, ...	Unterwalden Canton, . .	1847 + 2 ; 1856.	4
STANZA-PROTSCH-NOOK	OPSIN, Lake Kooban, Russia,	1825.	1
STASSFURTH, . . .	Saxony, ...	1880.	1
STATES OF THE CHURCH, .	. . . . .	1661 ; 1695 + 3 ; 1789.	6
STATI MOUNTAIN, between	Lombardy and Germany, .	1815 + 1.	2
STATONEG, . . .	Croatia, ...	1871 N.W.–S.E.	1
STATSBYDEN, . .	Norway, ...	1819 S.–N.	1
STAUDERNHEIM, . .	Homburg, S.W. Germany, .	1869 + 2.	3
STAVAGER, . . .	Switzerland, . . .	1852.	1
STAVELOT, . . .	Liège, Belgium, . . .	1828 + 2 ; 1867 ; 1873.	5
STAVERTON, . . .	Devon, ...	1865.	1
STAVROPOL, . . .	Astrakan, Causasus, . .	1827 + 3 ; 1851 E.–W. ; 1866 E.–W.	6
STCHEDRINSKAIA STANITZA,	Russia, ...	1848 + 4.	5
STEIN, ...	Baden, ...	1710 + 3.	4
STEIN, ...	Thurgau, ...	1858.	1
STEIN, . . . near	Krems, Lower Austria, .	1865.	1
STEIN, N.E. OF LAIBACH, .	Carniola, ...	1870 ; 1879 + 1 ; 1880 ; 1881 ; 1882.	6
STEIN, ...	Styria, ...	1857 ; 1868 E.–W.	2
STEINACH, . . .	Tyrol, ...	1878.	1
STEINAU, . . .	Cassel, Odenwald, . .	1869 + 1.	2
STEINBACH, . . .	Baden, ...	1822.	1
STEINBERG, . . .	Daun C., Rhenish Prussia, .	1869.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
STEINBRÜCKEN, . .	Styria, ...	(1877 + 2) W.–E. + 2 W.–E. ; 1881.	6
STEINEN, . . .	Schwytz C., . . .	1867 + 1.	2
STEINHEIM, . . .	"In der Rauchen Alp," .	1880.	1
STEINHOFF, . . .	Soleurs Canton, . . .	1837 + 1.	2
STEINPICHL, . . .	Carinthia, ...	(1857 + 2) N.–S.	3
STEINPICHL, . . .	Styria, ...	(1857 + 1) N.–S.	2
STEPENKOVITSCH, .	Lublin Gov., Poland, . .	1867.	1
STEPNEY, . . .	. . . . .	1755.	1
STIRLING, W., . .	. . . . .	1767 ; 1801.	2
STERNBERG, . . .	Brisgau, Baden, . . .	1824 ; 1857.	2
STERZING, . . .	Tyrol, ...	1873 S.E.–N.W.	1
STETTIN, . . .	. . . . .	1786.	1
STEUDERNHEIM, . .	Nahe Valley, . . .	1869 + 1.	2
STEUWEGG, . . .	Upper Austria, . . .	1785.	1
STEYERECK, . . .	Upper Austria, . . .	1785 + 3.	4
STIELDORF, . . .	Siebengebirge, . . .	1856.	1
STIRENZEN, . . .	Uri Canton, . . .	1774 + 7.	8
STOBZENHEIM, . .	Fichtelgebirge, . . .	1824.	1
STOCKACH, . . .	Würtemberg, . . .	1851.	1
STOCKACH River, . .	Baden, ...	1881.	1
STOCKHEIM, . between	Mein and Lahn, . . .	1869.	1
STOCKHOLM, . . .	. . . . .	1823 ; 1829 ; 1851, extended from Stockholm to Poisgrund, Norway ; 1853.	4
STOCKPORT, . . .	. . . . .	1750.	1
STOCKSTADT, . .	Bavaria, ...	1869 + 15.	16
STOFA, ...	Zurick Lake, ...	1826.	1
STOKE-SUB-HAMILTON,	. . . . .	1868.	1
STOLLBERG, . . .	Rhenish Prussia, . . .	1869 ; 1877 ; 1881.	3
STOLPEN, . . near	Dresden, Bavaria, . .	1862.	1
STORA, ...	Algeria, ...	1856 + 250 (from 22nd August to 12th September some shocks every three or four hours), + 4.	255
STRABANE, . . .	. . . . .	1880.	1
STADA, ...	Lower Engadine, . .	1882.	1
STRASBOURG, . .	. . . . .	1355 ; 1556 ; 1570 + 3 ; 1571 ; 1577 + 3 ; 1655 ; 1699 + 2 ; 1721 ; 1728, extended 30 leagues from E.–W., + 8 ; 1755 ; (1774 + 3) W.–E. ; 1784 ; 1801 ; *1802* S.W.–N.E. + 14 ; 1805 ; 1808 ; 1823 ; (1825 + 3) N.E.–S.W. ; (*1829 + 3*) N.–S. ; (1830 + 3) S.W.–N.E. ; 1843 ; 1846 + 1 ; 1855 E.–W. ; 1857 ; 1871 E.–W. ; 1876 ; 1878 ; 1880.	71
STRASSBURG, . .	Corinthia, ...	1767 ; 1867.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
STRASSIN, . . .	Hungary, ...	1848.	1
STRATHEARN, . .	Scotland, ...	1860 ; 1867.	2
STRATTON, . . .	Hereford, ...	1871.	1
STREZNO, . . .	Hungary, ...	1858 + 15.	16
STROEMSTADT, . .	Sweden, ...	1851, extended from Stroemstad to Gottenburg 150 km., + 3 S.E.–N.E.	4
STROMBERG, . . .	Nahe Thal, Rh. Prussia, .	1869.	1
STROMBOLI, . . .	. . . . .	1823 ; 1882 + 5 + 2 N.–S.	9
STROME, ...	. . . . .	1880.	1
STRONTHIAN, . .	. . . . .	1732.	1
STROWART, . . .	Erne Valley, Scotland, .	1870 + 1.	2
STRÜTH, ...	Rheingau Circle, . . .	1869.	1
STUBITZAWALD, . .	Agram, Croatia, . . .	1880.	1
STUDENA, . . near	Klana, Illyria, . . .	1870 + 1.	2
STUHLWEISSENBURG, .	Hungary, ...	1813.	1
STURMINSTER, . .	Dorset, ...	1761.	1
STUTTGARD, . . .	. . . . .	*1771 + 1* ; 1787 + 1 ; 1822 ; 1837 E.–W. + 1 ; 1855 + 2 + 2 N.E.–S.W. ; 1861 + 2 ; 1869 + 1, area shaken 30 geographical miles N.–S. by 18 geographical miles E.–W. ; 1871 + 2 ; 1872 ; 1874 + 2 ; 1880.	25
STYRIA, ...	. . . . .	1767 ; 1794 ; 1804 ; (*1811 + 1*) S.E.–N.W. ; 1813 ; 1839 ; 1840 S.–N. ; 1841 ; 1876 ; 1878 N.W.–S.E. ; 1880 + 1.	13
STYRIA, LOWER, . .	. . . . .	(1878 + 1) S.E.–N.W.	2
SUBBIANO, . . .	Arezzo, Italy, . . .	1823.	1
SUBIACO, ...	. . . . .	1868 ; 1871 + 1.	3
SUCZAWA, . . .	Russian and Rumanian [Frontier,	1880 S.W.–N.E.	1
SUDDEACH, . . .	Upper Austria, . . .	1839 S.W.–N.E. + 1 S.–N. ; 1840 S.–N. + 1.	4
SÜDERMANNLAND, .	Sweden, ...	1812.	1
SUDETES MOUNTAINS, .	Silesia, Prussia, . . .	1552.	1
LUDOVIC, . . .	Kreutz Com., Hungary, .	1875 S.–N.	1
SUEDICH, . . .	Asia Minor, ...	1872, two-thirds of town destroyed.	1
SUEZ, ...	. . . . .	1863.	1
SUFFOLK COUNTY, .	. . . . .	1165 ; 1201 ; 1750 ; 1869.	4
SUGATAGH, . . .	Marmaros Com., Hungary, .	1859 + 1 W.–E.	2
SULDEN, ...	Tyrol, ...	1877 N.E.–S.W. ; 1878.	2
SULI FORTRESS, . .	Albania, ...	1854.	1
SULMONA, . . .	Abruzzi, ...	*1830 + 1* ; 1841 + 2 ; 1845 + 1.	7
SULZ, ...	Würtemberg, . . .	1822 + 1.	2
SUNDBAU, . . .	Solothorn Canton, . .	1836.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SUNDBURY, . . .	Middlesex, ...	1865.	1
SUNDERLAND, . .	. . . . .	1871.	1
SUNDHEIM, . . .	Weimar, S.W. Germany, .	1825 N.E.–S.W. + 2.	3
SUNDI, ...	15 versts from Schemaka, [Caucasus,	1869, town destroyed.	1
SUNDRAL, . . .	Sweden, ...	1777.	1
SUNULENDIGA District,	Iceland, ...	1734.	1
SURA, ...	Irak-Arabia, Asia Minor, .	(1876 + 11) N.E.–S.W + 10.	22
SURAM, ...	50 miles S. of Oni, Armenia,	1878.	1
SURREY, ...	. . . . .	1750.	1
SUS, ...	Engadine, ...	1860 + 2.	3
SUSA, ...	Piedmont, ...	1753 ; 1773 ; 1785 ; 1809 ; 1878 ; 1881 + 1.	7
SUSAK, . . . near	Klana, Illyria, . . .	1870.	1
SUSSEX, ...	. . . . .	1734 ; 1861.	2
SUTHERLAND, . .	. . . . .	1690.	1
SUTOMORE, . . .	Dalmatia, ...	1881 + 1 N.–S.	2
SUTTON, ...	. . . . .	1727.	1
SVICA, . . . near	Zeng, Croatia, . . .	1870 + 3.	4
SWABIA, ...	. . . . .	1601, violent ; 1690 ; 1755, violent, + 1 ; 1802.	5
SWABIAN ALPS, . .	. . . . .	(1828 + 1) S.W.–N.E. ; 1830 + 4.	7
SWANSEA, . . .	. . . . .	1775 ; 1812 ; (1832 + 3) S.W. by W.–N.E. by E.	6
SWARDSJO, . . near	Fahlun, Sweden, . .	1831 N.–S.	1
SWATZ, ...	Tyrol, ...	1820.	1
SWEDEN, ...	. . . . .	1729 + 3 ; 1753 ; 1755 ; 1827 + 1 ; 1853.	9
SWEDEN, Northern, .	. . . . .	1843 + 3.	4
,, Southern, .	. . . . .	1843.	1
,, S.-Western, .	. . . . .	1873 E.–W.	1
SWITZERLAND, . .	. . . . .	802 ; 829 ; 858 ; 867 ; 1001 ; 1117 ; 1128 ; 1146 ; 1170 ; 1180 ; 1183 ; 1290 ; 1346 ; 1348 ; 1350, a mountain cleft ; 1378 ; 1382 ; **1394** ; 1500 ; 1523 ; 1533 + 3 ; 1572 ; 1577 + 4 ; 1578 ; 1584 + 10 (lasted 10 days) ; 1601, violent ; 1611 ; 1616 ; 1618 ; 1625 ; 1674 ; 1681 ; 1682 + 3 ; 1684 ; 1690 S.W.–N.E. ; 1692 ; 1699 + 3 ; 1720 ; 1721 ; 1728 ; 1729 ; 1736 ; 1753 + 1 ; 1755 + 1 ; 1756 ; 1802 ; 1822 ; 1826 ; 1837 ; 1839 ; 1850 ; 1851 + 2 ; 1855 + 2 ; 1860 ; 1869 ; 1880, centre in Monte Rosa, + 1 ; 1881, centre in the Upper Vaud Canton, + 1, extended into Italy, and to Calabria and Sicily, + 1 S.W.–N.E., limits of area shaken—Jura, Geneva, Tessin, Landquart, Feldkirch, Bodensee, Schaffhausen, Waldshut, Stockach, Horb,—strongest at Catanzarro, + 1.	89
SWITZERLAND, N.-Western, ...		1836 ; 1878, confined to the Jura formation surface.	2
,, Eastern, ...		1852 ; 1877 + 1 ; 1881 + 2 ; 1882.	7
,, Central, ...		1877 + 1 ; 1879.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
SWITZERLAND, WESTERN		1877, outside limits—Valence to S., Mulhausen N., Besançon W., Berne E., or Lyons W., and Siblen in Valais E.,—general direction of axis of area shaken, S.W.–N.E.	1
,, S.-EASTERN,		1878.	1
SYMI ISLAND,	Sporades,	1863 ; **1869** + **5**, destructive.	7
SYRA ISLAND,	Grecian Archipelago,	1856 ; 1866 ; 1881 ; 1882 + 4.	8
SYRACUSE,		A.D. 127 ; 494 ; 1086 ; 1716 ; 1717 + 3 ; 1719 + 3 ; 1757 ; 1769 ; 1823 ; 1846, violent ; 1856 ; 1866 ; 1869 ; 1871 S.W.–N.E. ; 1878.	21
SYRIA,		A.D. 287 ; 307, Tyre and Sidon greatly injured ; 550 ; 658 ; 713 ; 717 ; *746*, violent ; 749 ; 856 ; 860 ; 1032 ; 1034 ; 1063 ; 1069 ; 1114 ; 1115, violent ; 1138 ; **1158**, 20,000 people perished ; 1170, exceedingly violent—extended to Hungary, Germany, Switzerland, Sicily, and north coast of Africa ; 1182 ; **1183**, more than 20,000 lives lost ; 1201 ; 1204 ; **1334**, many and violent shocks ; 1402 ; 1666 ; 1760 + 3 ; *1819* + *1* ; **1836** + 6.	39
SYRIAN COAST,		**1759**, extended over a space of 100 leagues squares—the centre supposed to be at Sapphur, + 3 ; 1860 + 1.	6
SZAKOS,	Hungary,	1869.	1
SZANTO,	Zalah Com., Hungary,	1881 + 2.	3
SZATHMAR COM.,	Hungary,	1786 ; 1829 ; 1835 + 1 ; 1859.	5
SZEGEDIN,	Hungary,	1879.	1
SZEGSZEND = SZEKSARD,	Hungary,	1881 + 1.	2
SZENTES,	Hungary,	1881 + 3.	4
SZIGETH,	Marmaros Com., Hungary,	1830 ; 1844 + 1 ; (1858 + 2) S.E.–N.W. ; 1859 ; 1860 S.W.–N.E. ; 1869.	9
SZINITZ,	Styria,	1852.	1
SZINNA,	Hungary,	1857.	1
SZLIAS,	Galicia,	(1855 + 1) N.–S.	2
SZOMOLANG,	Presburg Com., Hungary,	1870.	1
SZONEG,	Hungary,	1879.	1
SZORTE,	Hungary,	1861.	1
SZURDOK,	Marmaros Com., Hungary,	(1859 + 1) S.–N.	2
TABARICH,	Syria,	1836, produced hot springs.	2
TABRIS, TABRITZ, TAURIS, TEBRIS,	Persia,	**1040**, 50,000 people perished ; 1273 ; **1640**, simultaneously at Damascus ; 1662 ; **1721**, the city entirely ruined, and more than 8000 lives lost ; **1727**, town ruined, and 77,000 lives lost ; **1755** + **1** ; *1780* ; 1787 ; 1819 + 6 ; 1855 + 3 ; (1856 + 1) N.N.E.–S.S.W. E. 23° 16′ N.–W. + 1, W. 31° 12′ S. ; *1857* + *1* ; 1858 + 1 ; 1868 ; 1869 N.–S., very violent ; (1870 + 1) N.–S. ; 1874, violent ; **1879** ; 1881, severe.	35
TAESCH,	Valais,	1862.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
TAGGENBURG Valley, .	St. Gall Canton, . . .	1881.	1
TAGGIA, ...	Pignerol, Piedmont, . .	1831 + 1.	2
TAHORA, ...	Neusohl, Hungary, . .	1862.	1
TAIN, ...	Drôme, ...	1754 + 1.	2
TALANO Canton, . .	Corsica, ...	1827 + 1.	2
TALANTA, . . .	Locris, Greece, . . .	1853 + 1.	2
TALBU, ...	Austria, ...	1837.	1
TALSCHYN KHANAT, .	Ararat Mountains, . .	1840 + 6.	7
TALZMAT, . . .	Algeria, ...	1860 + 1.	2
TAMOSE, ...	Upper Italy, . . .	1873.	1
TAMSWEG, . . .	Styria, ...	1881.	1
TANHEIM, . . .	Tyrol, ...	(1882 + 1) W.–E.	2
TANGIER, . . .	Morocco, ...	1755 + 6 ; 1773 E.–W., town almost ruined, + 20 ; 1785 ; 1841 + 1 ; 1863.	32
TAPIO-SZELE, . .	Hungary, ...	1868.	1
TARANTO, . . .	Terra di Otranto, . .	1851 ; 1858 ; 1881.	3
TARASCON, . . .	. . . . .	1763.	1
TARASP, ...	Grisons, ...	1857 ; 1860 + 2 ; 1869 ; 1871 ; 1880 ;	7
TARBES, ...	. . . . .	1750 + 6 ; 1835 W.–E., radius = 5 leagues, + 1 ; 1850 ; 1852 + 3 ; 1854 + 3 + 2 S.W.–N.E. ; 1855 ; 1856 ; 1862 ; 1867 + 1 ; 1868 + 1 W.–E. ; 1869 N.–S. ; 1870 ; 1878 S.–N.	30
TARBRIS, . . .	Carinthia, ...	1855 W.–E. ; 1857 S.W.–N.E. + 1 W.–E. ; 1874 S.E.–N.W. ;	4
TARDES, ...	Carinthia, ...	1867.	1
TARDET, ...	Basses Pyrénées, . . .	1874.	1
TARK, ...	Northern Persia, . . .	1879.	1
TARN, ...	Pyrénées Orientales, . .	1824.	1
TARNING, . . .	Sussex, ...	1734.	1
TARNOW, ...	Galicia, Austria, . . .	1858.	1
TARNOWITZ, . . .	Galicia, Austria, . . .	1786 + 2 ;	3
TARRAGONA, . . .	Spain, ...	1817 ; 1845 ; 1856.	3
TARSUS, ...	Asia Minor, . . .	1855.	1
TARVIS, ...	Carinthia, ...	1856 S.W.–E. ; (1863 + 2) E.–W. + 3 ; 1866 + 2 ; 1867 ; 1879 ; 1881 ; 1882.	13
TASCHKENT, . . .	Turkestan, Russia, . .	1823 ; 1868 S.W.–N.E. + 2 ; 1869 ; 1870 ; 1871 + 1 ; 1876, earthquakes rather frequent in the province of Turkestan ; as, in general, in Central Asia ; the most violent in March and in February ; generally five earthquakes per year.	9
TASSO, ...	Africa, ...	1755.	1
TATZA, ...	Asia Minor, . . .	1869.	1
TAUFERS, . . .	Tyrol, ...	1862.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
TAUHERBISCHOFSHEIM,	Baden,	1869 + 1 ; 1873 ; 1874.	4
TAUNTON,		1738 ; 1748 ; 1863.	3
TAUNUS MOUNTAIN,		1846, extended over a polygonal area of which the summits were Pyrmont N., Liège and Namur W., Nancy S., Stuttgart and Wurtzbourg E.	1
TAURIDA GOVERNMENT,	Russia,	1823 + 1 ; 1869 + 1.	4
TAURIS,	Persia,	*See* Tabris.	
TAUS,	Bohemia,	1858.	1
TAUSENERTHAL,	Tyrol,	1862.	1
TAUXIGNY,	Indre et Loire,	1855.	1
TAVARO CANTON,	Corsica,	1827 + 1.	2
TAVEL,	Languedoc,	1840.	1
TAVERNA,	Hungary,	1778 + 11.	12
TAVERNILLA,	Tuscany,	1858.	1
TAVIRA,	Portugal,	1856 + 5.	6
TAVISA,	Cataluña,	1845 + 9.	10
TAVISTOCK MINE,	Devon,	1852.	1
TAXENBACH,	Tyrol,	1862.	1
TCHEMKENT,	Turkestan, Russia,	1868 + 1.	2
TCHEROLEN,	43° 30′ Lat., 43° 30′ Long., Caucasus,	1853 + 1.	2
TCHEWLENSKAIA STANITZKA,	Russia,	1848 + 2.	3
TCHINAZ,	Turkestan,	1868 + 1.	2
TEBRIS,	Persia,	*See* Tabris.	
TEBRIZ-KAPOUÇOU,		1859.	1
TECSO,	Marmaros Com., Hungary,	(1856 + 1) S.–N. ; 1860 S.W.–N.E. ; 1870.	4
TECUCIN,	Moldavia,	1878 + 3 ; 1880 + 3.	8
TEGERN SEE,	Bavaria,	1873.	1
TEGINGO,	North Italy,	1802.	1
TEHERAN,	Persia,	1830 + 3 ; *1847*.	5
TELAF,	Tiflis Gov., Caucasus,	1853 ; 1868 E.–W.	2
TELAVI,	Georgia,	1867 N.W.–S.E.	1
TELLAM SEE,	Tyrol,	1862.	1
TELLMARKEN,	Norway,	1834.	1
TEMESWAR,	Servian Woiwod, Austria,	1763 ; 1794 + 4 ; 1802 ; 1819 + 2 ; 1843 N.N.W.–S.S.E. ; 1855 ; 1857 + 1 ; 1858 + 1 ; 1864 + 1 ; (1865 + 1) W.–E. ; 1866 ; 1869 ; 1879 + 3 ; 1880.	27
TENBY,	Pembrokeshire,	1864.	1
TENDE,	Piedmont,	1849 + 1.	2
TENES,	Algeria,	1854 + 1 ; 1857 + 1 ; 1859 ; 1862 ; 1864 + 3 ; (1868 + 1) E.–W. + 2 + 1 S.–N. ; (1871 + 4) S.–N. ; 1873 N.E.–S.W.	21

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
TENEDOS ISLAND,		1766 ; 1771 ; 1853 ; 1859 + 2.	6
TENIET-EL-HAAD MTN.,	The highest in Algeria,	1851 ; 1867.	2
TEODORANO,	Italy,	1870.	1
TEPLEN,	Epirus,	1860 + 5.	6
TEPLITZKA,	N.W. Hungary,	1858 + 2 ; (1864 + 7) S.–N.	11
TERAMO,	Abruzzi,	1809 ; 1825 + 1 ; 1827 ; 1842 ; 1858.	6
TER-GOES,	Beveland Island, Holland,	1848 N.E.–S.W. + 3.	4
TERNI,	Spoleto, Italy,	1703 ; 1785 + 38 ; 1786 + 3 + 1, extended to Rome, + 2, and all the plain to the foot of the Apennines, + 10 ; 1787 + 2 ; 1790 ; 1863 ; 1868 E.S.E.–W.N.W. ; 1881 + 18.	82
TERNOVA, near	Diakovar, Sclavonia,	1859 S.E.–N.W.	1
TERRACINA,	Frosinone, Italy,	1857.	1
TERRA DI BARRI,		1088 ; 1689 ; 1806, extended along a line S.E.–N.W. between the coast of the Tyrhenian Sea and the S.W. spur of the Apennines, + 3 ; 1826 ; 1845 ; 1851.	9
TERRA DI LAVORO,		**1654** + 2, continued 20 days, extended in a line S.–N. a little E. from Pontecorvo to Alvito ; 1694 ; **1732** ; 1770 ; 1805 ; 1858.	26
TERRA NOVO,	Calabria,	1638.	1
TERRA NOVO,	Caltanissetta, Sicily,	1852.	1
TERRA PILATA,	Sicily,	1823 S.E.–N.W., ground rose 10 feet—clefts of 10–18 inches wide opened, and eruption of gas and mud took place from two mud volcanoes.	1
TERRUEL,	Portugal,	1761 + 2.	3
TESCHEN,	Silesia, Poland,	1715, oscillations for 36 hours ; 1786.	2
TESSERATE,	Tessin Canton,	1853.	1
TESSIN CANTON,		1851 E.–W. ; 1870 W.N.W.–E.S.E. ; 1880 ; 1881.	4
TESSY,	Manche,	1846.	1
TETUAN,	Marocco,	*1775 + 8.*	9
TEVERZAL,	Nottinghamshire,	1881.	1
TEWKESBURY,		1574.	1
THAINGEN,	Schaffhausen Canton,	1855.	1
THASIS ISLAND,	Grecian Archipelago,	1829 N.W. + 3, and opposite coast of Macedonia to Adrianople.	4
THEBES,	Upper Egypt,	B.C. 31–30.	1
THEBES,	Greece,	1835 ; *1853 + 33*, centre at Monte Ploo, extended to province of Livadia, Chalcis, and Attica, + 73 ; 1854 + 10 ; 1859 ; 1879.	121
THEIS,	4 miles from Grenoble,	1790.	1
THEODOSIA,	Crimea,	1869.	1
THERA ISLAND,	Greece,	1866 + 2.	3
THESSALONICA,		1761 S.W.–N.E. + 3 ; 1783.	5
THESSALY,		1864 ; 1868 + 2 ; 1869 + 2.	6

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
THEUX,	Belgium,	1867 N.W.–S.E.	1
THIERRENS,	Switzerland,	1846.	1
THIERS,	Puy de Dôme,	1877 N.–S. ; 1881.	2
THIONVILLE,		1846.	1
THOARD,	Var,	1866.	1
THORÆ ISLAND, near	Funen, Denmark,	1776.	1
THOUDA, near	Biskra, Algeria,	1869 + 1.	2
THOUNE = THUN,	Berne,	1809 ; 1817 ; 1855 S.W.–N.E. ; 1856 ; 1881 + 3.	6
THRACE,		A.D. 447 ; 458 ; 740 ; 815 ; 927, the earth opened ; 1064 ; 1273 ; 1354 ; 1829 + 3 (coast of).	12
THRALES,		B.C. 25–22.	1
THRELKELD,		1787.	1
THUN,		1880.	1
THUN LAKE,		1729.	1
THURGAU Canton,		1705 ; 1720 ; 1755 ; 1852 ; 1858 ; 1877.	6
THURINGIA,		1088 ; 1326 ; 1332 ; 1368 ; 1558 ; 1682 ; 1690 ; 1785.	8
THURINGIAN FOREST, THURINGERWALD,	S.W. part of,	1847, very violent.	1
THURNAU,	Lower Bavaria,	1858 + 1.	2
THUROCZ Com.,	Hungary,	1858.	1
THURTHAL,	St. Gall Canton,	1881.	1
THUSIS,	Grisons,	1853.	1
THYATIRE,		B.C. 25–22.	1
THYMSORE-SYSSEL,	Iceland,	1724, very violent.	1
TIANO, near	Naples,	1765 + 1.	2
TIBERIAS,	Syria,	*1836.*	1
TIBERIAD,		1856.	1
TIBISSORDE,	Syria,	**1836**, town ruined.	1
TICINO Valley,		1880.	1
TIEDALI,	Tuscany,	1851.	1
TIEF HARTMANNSDORF,	Silesia,	1778.	1
TIFLIS,	Georgia,	1803 : 1804 + 31 1805 + 2 ; (1811 + 1) S.–N. ; 1819 + 6 ; 1820 + 1 ; 1821 + 2 ; 1827 S.E.–N.W. + 10 ; 1830 N.–S. ; 1832 + 8 ; 1840 + 5 ; 1841 + 1 ; 1842 ; 1844 N.W.–S.E. + 2 . 1846 ; 1847 + 3 ; 1851 + 1 E.–W. + 2 ; 1852 + 2 ; 1853 + 1 N.–S. + 1 ; 1853 N.W.–S.E. ; 1854 ; (1855 + 1) N.W.–S.E. + 3 ; (1856 + 2) N.W.–S.E. + 3 S.W.–N.E. + 3 ; 1859 + 1 ; 1860 S.E.–N.E. ; 1862 + 2 N.W.–S.E. ; 1864 ; 1865 N.W.–S.E. ; 1867 + 2 + 1 N.N.E.–S.S.W. ; (1868 + 1) N.W.–S.E. + 12 + 1 N.W.–S.E. + 1 N.N.E.–S.S.W. + 1 W.–E. ; (1868 + 2) N.–S. + 6 + 2 E.–W. ; 1869 N.W.–S.E. + 1 ; (1870 + 3) N.W.–S.E. + 1 W.–E. ; 1880 + 1 S.–N. ; 1881.	164

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
TIGVING,	Carinthia,	1856 S.W.–N.E.; 1857 + 1 W.–E.; 1862 N.–S.	4
TILBURG,	Holland,	1843.	1
TILLACH,	Tyrol,	1848.	1
TILLY LE CAMPAGNE,		1837.	1
TINAHELY,	Co. Wicklow, Ireland,	1869.	1
TINTINHALL,		1868.	1
TINWELL, Parish,	Rutland,	1844.	1
TIONE,	Tyrol,	1880.	1
TIONE RIVER,	Northern Italy,	1851 + 7; 1852 + 3.	12
TIPATZA,	Algeria,	1867.	1
TIRANO,	Sondrio, Italy,	1851; 1852 W.–E.	2
TIRASPOL,	Cherson Gov., South Russia,	1829; 1854; 1880 S.E.–N.W.	3
TIRLEMONT = TIENEN,	Brabant, Belgium,	1828.	1
TIRIOLA,	Calabria,	1869.	1
TISCHEN,	Carniola,	1878.	1
TISCHNOWITZ,	Moravia,	1876.	1
TITO, Il,	Basilicata,	*1857 + 5.*	6
TIVISA,	Cataluña,	1845 + 2.	3
TIVOLI,		1695; 1730 + 3; 1752; 1754; 1774; 1778 + 1; 1785 + 2; 1791 + 1; 1811 + 1; 1842 E.–W.; 1868 N.W.–S.E. + 1.	20
TIXOVER,		1844.	1
TIZI-OUZORI,	Algeria,	1867 W.–E.	1
TLELAT,	Algeria,	(1875 + 3) N.–S.	4
TLEMCEN,	Algeria,	1858; 1871 + 3.	5
TOBELBAD,	Styria,	1868 E.–W.	1
TOBERMORY,	Mull,	1880.	1
TOCHATACH,	Caucasus,	1862 S.E.–N.W.	1
TODIANO, near	Norcia,	1859 + 2.	3
TODMORTON,		1869.	1
TODTNAU,	Baden,	1881 + 1.	2
TÖPLITZ,	Carinthia,	1755, very violent.	1
TOERBEL,	Valais,	1850; 1853; 1854 N.–S.; 1855 + 61; 1856 + 46 + (June) 8, (July) 6, (August) 25, (September) 6, (October) 10, (November) 4.	171
TOGGENBURG Valley,	St. Gall Canton,	1705.	1
TOISY,	Côte d'Or,	1838.	1
TOKAY,	Hungary,	1868 + 4.	5
TOLE,	Bologna,	1864.	1
TOLEDO,		1113; 1169; 1817.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
TOLENTINO,	Macerata, Italy,	1791 + 23.	24
TOLMEN,	Goritz, Austria,	1876.	1
TOLMEZZO,	Venetian Territory,	*1788*; 1870 + 12; 1881 + 2 + 1 N.–S.	18
TOLNAU = TOLNA,	Hungary,	1881 + 1.	2
TOLOSA,		1854 N.–S.	1
TOLVE,	Basilicata,	1845.	1
TOMBAY,	Verona District,	1880.	1
TONGRES,	Belgium,	1865; 1878.	2
TONNEINS,	Lot et Garonne,	1854.	1
TONNINGIN,	Jutland,	1805.	1
TONSBERG,	Norway,	1858.	1
TOOTING,	England,	1750.	1
TOREGNY,	Manche,	1846.	1
TORINA,	Andalucia,	1504.	1
TORINO DEL SANGRO,	Abruzzi,	1880.	1
TORKI,	Caucasus,	1830.	1
TORMOS,	Alicante Province,	1856 + 2; 1857 + 1.	5
TORNAEZ, near	Neutra, Hungary,	1873.	1
TORNEA,	Lapland,	1757; 1780; 1826 S.–N.	3
TORONTAT Com.,	Servian Woiwod, Austria,	1879.	1
TORRE Del Anunziata,	Napoli,	1881.	1
TORRE Del Greco,	,,	1752; 1861 + 72, fissure opened between vertical axis of Vesuvius and Torre de Greco, followed by an eruption; 1867; 1868 + 1; 1881 + 2.	80
TORRE De Montcorvo,	Traz os Montes Province,	1752.	1
TORREL LA MATA,	Spain,	1802 + 3.	4
TORRE DI PASSERI,	Abruzzi,	1841; 1842; 1843 + 1; 1844 + 2; 1845.	8
TORRE MAGGIORE,	Naples,	1852.	1
TORRE MILETO, near	Cape Gargano,	1871 + 4.	5
TORRES VEDRAS,	Portugal,	1790.	1
TORRENI,	Tuscany,	1849.	1
TORRITA,	Arrezo,	1849 E.–W. + 5.	6
TORRE VIEJA,	Valencia, Spain,	1802 + 3; 1828 + 12; 1829 + 273 + *16* + **1**; 1833 + 2; 1837 + 400; 1858 + 5 + 1 E.–W.; 1859 + 3; 1860 S.W.–N.E. + 19 + 3 N.–S.; 1861 + 18 + **1** E.–W., very violent, + 1 W.–E.; (1862 + 29) S.–N. and S.E.–N.W. + 4; 1863 + 7; 1864 + 1, violent, + 3 + 1 S.E.–N.W. + 1 W.–E.; 1867 + 2.	819
TÖRSBURG,	Transylvania,	1855 S.E.–N.W.	1
TORTONA,	Calabria,	1708; 1780 + 3; 1867 + 1; 1882 + 2.	10
TORTOSA,		1395 + 3.	4

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
TOSCANELLA, . . .	Viterbo, ...	1881 S.E.–N.W.	1
TOSSIGNANO, . . .	Ravenna, ...	1881 + 3.	4
TOULON, ...	Var, ...	1708 ; 1854 N.–S. ; (1866 + 1) E.–W. ; 1870 + 2.	7
TOULOUSE, . . .	. . . . .	1743 + 1 ; 1747 ; 1750 ; 1752 + 1 ; 1765 N.–S. ; 1775 N.W.–S.E. ; 1854 + 3 ; 1855 ; 1870.	14
TOUR DE PEILZ, . near	Vevey, Switzerland, . .	1882.	1
TOURNAI, . . .	Belgium, ...	1881.	1
TOURNON, . . .	Vivarais, ...	1775.	1
TOURNUS, . . .	Seine et Loire, . . .	1784 ; 1871.	2
TOURS, ...	. . . . .	1295 ; 1579 ; 1822 ; 1840.	4
TOUZLA, ...	Zwarnick District, Bosnia, .	1858.	1
TRACY, ...	South Coast, England, .	1878.	1
TRAFAYASH, . . .	Styria, ...	1863.	1
TRAKOSTYAN SCHLOSS,	Agram, ...	1880 + 5.	6
TRAMUTOLA, . . .	Basilicata, ...	1857, very violent, + 5 ; 1858 + 2.	9
TRANI, ...	Terra di Barri, . . .	1806 ; 1851.	2
TRANSYLVANIA, . .	. . . . .	1747 ; 1790 ; 1793 ; 1802 + 1 ; 1829 ; 1838 + 3 ; 1864.	11
TRAPANI, . . .	Sicily, ...	1259 ; 1823 ; 1845.	3
TRARBACH, . . .	Rhenish Prussia, . . .	1869.	1
TRATTA, ...	Carniola, ...	1856, extended to Idria.	1
TRAUENWALD, . .	Thuringerwald, . . .	1831.	1
TRAUTENAU, . . .	Bohemia, ...	1857 + 1 ; (1882 + 1) S.W.–N.E.	4
TRAVNIK, ...	Lat. 44° 10′ N. Long. 15° 15′ E. Lr. Bosnia,	1859 + 3 ; (1860 + 3) N.–S.	8
TRAZ OS MONTES Prov.,	Portugal, ...	*1751.*	1
TREBINJE, . . .	Lower Bosnia,	1880 N.–S. ; 1882 W.–E.	2
TREBITSCH, . . .	Moravia, ...	1876.	1
TREBIZONDE, . . .	Black Sea, ...	1850 + 1 ; 1859 ; 1860.	4
TRECASTAGNI, . near	Catania, Sicily, . . .	1865 + 1 ; 1866 + 18 + 1 E.–W. ; 1868 ; 1869 + 1.	25
TREFFEN, . . near	Laibach, ...	(1871 + 3) S.W.–N.E. + 2.	6
TREIS, ...	Cochem C., Rhenish Prussia,	1869 S.–N.	1
TREMOLA VALLEY, .	Tecino, ...	1821 + 7 ; 1854 + 1.	10
TREMOSINE, . . .	Brescia, ...	1880.	1
TREMP, ...	Cataluña, ...	1853 + 5 E.–W.	6
TRENT, ...	. . . . .	1703 ; 1756 ; 1785 ; 1810 ; 1812 ; 1826 + 1 ; 1827 + 1 ; 1859 E.–W. ; 1861.	11
TRENTE VALLEY, . .	. . . . .	*1120* + 37 (seven, ten, and even twenty shocks felt each day) ; 1419 ; 1876.	40
TRENTSCHIN Com., .	Hungary, ...	1782 ; 1858, extended over greater part of Moravia, Galicia, and Silesia ; area = 78·200 km. c., + 46.	48

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
TREPORT, . . .	Normandy, ...	1882 N.W.–S.E.	1
TRESILICO, . . near	Oppido, Calabria, . .	1852 + 19.	20
TREVES, ...	. . . . .	1841 ; 1855 ; (1869 + 2) N.–S. + 2 S.E.–N.W.	7
TREVI, . . . near	Foligno, ...	1832.	1
TREVISA, ...	. . . . .	778 ; 1365 ; 1511 ; 1756 + 1 ; 1812 ; 1836 + 17 ; 1857 ; 1859 ; (1860 + 1) E.–W., area shaken, extended from the Valley of Belluno to Rovigo, and from Verona to Trieste, 1880.	29
TRIBAU, ...	Poland, ...	1786.	1
TRIBUR, ...	Rhine Valley, . . .	1869.	1
TRICALA, . . .	Macedonia, ...	1843.	1
TRIEBEN, . . .	Styria, ...	1873 E.W.	1
TRIESTE, ...	. . . . .	*1648*, town destroyed ; 1762 + 2 ; (1776 + 4) W.–E. ; 1778 ; 1802 ; 1827 N.–S. + 1 ; 1828 ; 1834 ; 1835 S.–N. ; 1838 + 4 ; 1840 ; 1843 ; 1844 N.–S. ; 1845 N.W.–S.E. + 5 + 1 S.–N. ; 1846 N.–S. ; 1850 + 3 ; 1851 + 8 ; 1853 ; 1855 ; 1856 + 3 + 1 N.E.–S.W. ; 1857 + 3 + 1 S.E.–N.W. ; (1858 + 2) N.E.–S.W. ; 1859 + 1 ; 1860 + 1 ; 1861 + 3 ; (1864 + 1) N.W.–S.E. ; 1866, + 2 ; 1870, simultaneously at Fiume, + 9 + 2 W.–E. + 2 E.–W. + 2 S.E.–N.W. ; (1873 + 3) S.–N. + 2, extended mainly to the N.W. ; 1875 ; 1879 ; 1880 ; (1881 + 6) N.E.–S.W. ; (1882 + 1) N.W.–S.E.	107
TRIFILAKI, . . .	Missolonghi, Greece, . .	1852 + 1.	2
TRIPOLI = TRIPOLIS, .	Syria, ...	494 ; 1063 ; 1155, 2000 lives lost ; 1158, violent ; 1183 ; **1759** + 3 ; 1760 + 1 ; *1764* ; 1783 + 1 ; 1836 ; 1860 + 1 ; 1861 + 1 ; 1863, extended from Smyrna and Malta ; 1872.	21
TRIPOLITZA, . . .	Mantinea, Greece, . .	1859 ; 1860 ; 1861 ; 1866 ; 1867 + 7 + 1 S.–N.	13
TRISAIL, ...	Styria, ...	1852 + 4.	5
TRITTENHEIM, . .	Rhine Valley, . . .	1869.	1
TROAD, ...	Asia Minor, . . .	447.	1
TROFAIACH, . . .	Carinthia, ...	1863 + 1.	2
TROGEN, ...	Appenzell Canton, . .	1880.	1
TROENA, ...	Sicily, ...	1822 ; 1853 + 1.	3
TROISDORF, . . .	Sieg C., Rh. Prussia, . .	1869.	1
TRÖLLEBURG, . .	Sweden, ...	1869.	1
TROMSOE, . . .	Norway, ...	1870.	1
TROPSCHACH, . .	Carinthia, ...	1879.	1
TRŒSIL, ...	Odenwald, ...	1872 + 1.	2
TROTSKOSAVSK, . near	Kiatcha, Siberia, . . .	1856 N.W.–S.E.	1
TROYES, ...	. . . . .	1682 ; 1855.	2
TRUBENHAUSEN, . .	Hesse, ...	1881.	1
TRURO, ...	. . . . .	1859.	1
TCHAMPITA, . . .	Alexandropol C., . . .	1869.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
TSCHASS-VINSCHGAU, .	Caucasus, ...	1862 S.E.–N.W.	1
TCHEBRAIL, . . .	Araxes Valley, . . .	1870 + 2.	3
TSCHERNEMBL, . near	Laibach, Carniola, . .	1871 ; 1880.	2
TSCHERNOWITZ, . .	Bohemia, ...	1860.	1
TSCHUBUCHLY . on	Gotschu Lake, Transcaucasia,	1853 + 10.	11
TÜBIGEN, . . .	Würtemberg, . . .	1855 + 2 ; 1874 + 5 ; 1875 + 1.	11
TÜFFER, ...	Lower Styria, . . .	1877 + 3 + 2 S.E.–N.W. ; 1880 ; 1881 N.E.–S.W. + 2 + 1 N.E.–S.W.	11
TULA, ...	S. W. Russia, . . .	1802.	1
TULTCHA, . . .	Bulgaria, ...	1868 + 12 + 2 S.–N. ; 1880 + 1 S.–N.	17
TULCAIN, . . .	Cherson Gov., . . .	1790.	1
TUNIS, ...	. . . . .	1758 + 1 ; 1863 + 17, a volcanic island rose in 37° 50′ N. lat. and 8° 50′ E. long., at 40 miles N.E. of the Cani Rocks ; 1864 + 4 ; 1881 + 3.	29
TUNIS, ...	Southern part of, . .	1881.	1
TURBOLE, . . .	Tyrol, ...	1870.	1
TURCLOT, . . .	Seine Inférieure, . .	1848.	1
TURGAU, ...	*See* Thurgau Canton, . .		
TURKESTAN, . . .	. . . . .	1868 + 1.	2
TURIN, . . , .	. . . . .	1753 + 2 ; 1755 S.N. ; 1756 + 1 ; 1767 + 3 ; 1775 ; 1791 ; 1802 ; 1808 N.W.–S.E. + 4 ; 1818 + 1 ; 1825 ; 1828 ; 1854 N.W.–S.W. + 1 ; 1855 + 2 ; 1858 + 1 ; 1866, felt also at Cuneo, Asto, St. Michale delle Chiese, Moncalieri Fossano, Pinerolo Dogliani, Mondovi, Cassine ; 1867 ; 1878 E.–W. + 1 ; 1881 + 1.	35
TURKEY IN EUROPE, .	. . . . .	1509 ; 1542 ; 1756 + 1 + 1 S.–N. ; 1791 ; 1794 ; 1802 ; 1828 + 1 ; 1829 ; 1838.	12
TURNHAM, . . .	. . . . .	1750.	1
TURN, ...	Fuime Dis., . . .	1870.	1
TURRAH, ...	Styria, ...	1855 N.E.–S.W. ; 1881 S.W.–N.E.	2
TURSI, ...	Basilicata, ...	1858 + 1.	2
TURTMANN, . . .	Tourtemaque, Valais, . .	1855.	1
TURZANO, . . .	Calabria Citra, . . .	1854.	1
TUSCANY, . . .	. . . . .	1345 ; 1356 ; 1385 ; 1542 + 5 ; 1558 ; 1571 ; 1593 + 3, very violent ; 1661 ; 1719 ; 1762 + 3 ; 1777 ; 1781 ; 1783 ; 1789 ; 1804 + 1 ; 1845 ; 1846 N.W.–S.E. very violent—the area most strongly shaken comprised between the Tuscan Coast and the first range of the sub Apennine hills—the coast line extended from the Arno to the Cecina river—on the mountain side the line passed by Lorrenzana, Orchiano, Riparbella, Montescudaio and Bibona—line of holes N.W.–S.E. ; 1853, centre at Pamarance and environs where are the Boracic acid Lagoni	30
TUTTLINGEN, . .	Wurtümberg, . . .	1828 ; (1855 + 2) W.–E.	4
TUTSCHOU, . . .	Bessarabia, ...	1827 + 1.	2
TWANN, ...	Berne Canton, . . .	1876.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
TYNDRUM,		1831 ; 1844.	2
TYNE River,		1871.	1
TYNE HEAD,		1865.	1
TYNEMOUTH,		1838.	1
TYRNAU,	Hungary,	1660 + 1 ; 1866 N.W.–S.E. ; 1870.	4
TYROL,		1222 ; 1348 ; 1670 ; 1755 + 1 ; *1756* + 3 ; continued for 3 weeks, + 21 ; 1772 ; 1812 ; 1820 ; 1826 ; 1851 + 1 ; 1856 ; 1861 + 1 ; 1869 ; 1873.	41
TYRE,		*1127*, many lives lost, the earth opened ; 1204.	2
TZAROKI-KOLODSKY,	Caucasus,	1853.	1
TZERNOOD,	Danubian Province,	(1868 + 3) W.–E.	4
UBEDA,	Andalucia,	1867 + 1.	2
UCKERATH,	Sieg C., Rhenish Prussia,	1869 N.N.W.–S.S.E.	1
UCTLIBERG,	Switzerland,	1855 + 1.	2
UDEN,	Zealand, Holland,	1843.	1
UDINE,	Italy,	1776 ; 1784 ; 1850 ; 1859 E.–W. ; 1869 ; 1872 + 2 ; 1876 ; 1880 ; 1881.	11
UEBERAU,	Rhine Valley,	1869 + 2.	3
UEBISCHI, near	Thierachern, Berne Canton,	1855.	1
UEDESHEIM,	Neuss Canton, Rh. Prussia,	1869.	1
UELMEN,	Rhine Valley,	1869 N.–S.	1
UETLIBERG,	Switzerland,	1855 + 1.	2
UGINIS,	Savoie,	1852.	1
UGLIAN CALDO,	Tuscany,	1778.	1
UGLIANE,	Dalmatia,	1837 + 31, extended from Genoa to Florence—centre of disturbance at Pizzo di Ucello, one of the highest of the Apuan Alps: the earth opened in several places.	32
UIG,	Scotland,	1880.	1
UJSZONY,	Hungary,	1851.	1
ULENSWANG,	Norway,	1834 + 2.	3
ULVERSTONE,		1863.	1
ULM,		1756 ; 1769 ; 1778 ; 1796 ; 1806 ; 1846 ; 1852 ; (1861 + 2) S.E.–N.E.	10
UMAN,	Kieff, Russia,	1821 + 2 ; 1880.	4
UMBRIA,		1751 ; 1832 ; 1873.	3
UMEA,	Westerboden, Sweden,	1872.	1
UMOLA,	Eastern Bothnia, Sweden,	1765.	1
UNDERS-VIK,	Sweden,	(1853 + 1) N.–S.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
UNKEL, ...	Neuwied C , Rhenish Prussia,	1869 S.W.–N.E. + 2.	3
UNTERBACH, . . .	Valais, ...	1855 + 6 ; 1856 + 76 ; 1857 + 13.	98
UNTERHAUSEN, . .	Swabia, ...	1828 + 1.	2
UNTERSCHALFER ALPE,	Carinthia, ...	1879.	1
UNTERSEE, . . .	Constance Lake, . . .	1855 + 2.	3
UNTERTAUEN, . .	Carinthia, ...	1862 + 2.	3
UNTERTURKHEIM, .	Würtemberg, . . .	1861.	1
UNTERWALD CANTON, .	. . . . .	1851.	1
UNTERWALLIS = LOWER	VALAIS, ...	1736 ; 1737 + 3 ; 1879 ; 1881 + 2.	9
UNTER ZEINUNG, . .	Upper Austria, . . .	1852 + 2.	3
UNST ISLAND, . .	Shetland, ...	1866, extended to Norway and Scotland.	1
UPBERGEN, . . .	Holland, ...	1828 + 1.	2
UPPER RHINE, . .	. . . . .	1356.	1
URACH, ...	Würtemberg, . . .	1828 ; (1830 + 2) W.–E.	4
URAL MOUNTAINS, .	. . . . .	1844.	1
URA TUBÉ, . . .	Caucasus, ...	1867 + 1 ; 1868 + 1 + 2 S.–N.	6
URBACH, ...	Mulheim C., Rhenish Prussia,	1869 + 1.	2
URBINO, ...	. . . . .	1694 ; 1752 + 1 ; 1850 + 2 ; 1851 + 1 N.W.–S.E. ; 1853 N.W.–S.E., very violent, strong along the line of Commachio, Imola, Fortis, Rimini, Pesaro, Sinagalia, Ancona, Macerta—100 geographical miles in extent, + 1 + 2 S.E.–N.W. ; 1854 N.N.E. + 6 + 3 E.N.E. + 4 S.W.–N.E. + 1 E.–W. ; 1855 ; 1856 W.–N.W. + 4 ; 1857 + 5 + 1 S.–N. ; 1859 + 4 + 1 N.E.–S.W. ; 1860 + 4 ; 1861 + 2 + 2 E.–W. ; 1862 N.W.–S E. + 1 ; 1863 ; 1865 + 2 + 1 N.W.–S.E. ; 1866 + 3 ; 1867 W.–E. + 5 ; 1868 + 6 ; 1869 + 3 ; 1870 + 7 ; 1871 + 1 + 1 S.W.–N.E. + 1 S.E.–N.W. ; 1875 ; 1881 + 2.	100
URBINO, DUCHY, . .	. . . . .	1752 + 3 ; 1781 + 2, shocks extended all along the Adriatic.	7
URI, ...	. . . . .	1879.	1
URI CANTON, . . .	. . . . .	1638 + 3 ; 1881.	5
URIAGE, ...	Isère, ...	1858.	1
URQUART, . , .	. . . . .	1817 + 1.	2
URRUQUE, . . .	Pyrénées, ...	1853.	1
USHAK, ...	Anatolia, ...	1874, violent, + 1.	2
USHINISH, . . .	Scotland, ...	1880.	1
USK, ...	. . . . .	1865.	1
USLER, ...	Zurich Canton, . . .	1672.	1
USSON, ...	Puy de Dôme, . . .	1881.	1
UTRECHT, PROVINCE, .	. . . . .	1342 ; 1878.	2
UTRECHT, . . .	. . . . .	1760 + 2 ; 1833.	4
UTSTOK, ...	Hungary, ...	1880.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
VAALS, ...	Limburg, Netherlands, .	1873.	1
VAGEL, ...	Austrian Poland, . . .	1840 + 2.	3
VAIHINGEN, . . .	Würtemberg, . . .	1875 N.W.–S.E.	1
VAIVRE, ...	Haute Saône, . . .	1780 W.–E.	1
VAJNASALVA, . . .	Transylvania, . . .	1876.	1
VALAIS CANTON, . .	. . . . .	1552; 1572; 1633; 1684; 1692 + 1; 1712; 1715; 1755; 1847 + 3; 1855; 1856 + 3; 1869 + 1; 1877; 1881 + 4; 1882.	27
VALAIS, UPPER, . .	. . . . .	1746.	1
VALAIS, LOWER, . .	*See* Unterwallis.		
VAL BREGAGLIA, . .	Southern Alps, . . .	1882.	1
VALCABRÈRE, . .	Haute Garonne, . . .	1835.	1
VAL DI CHIANA, . .	Tuscany, ...	1848.	1
VALDEMONE, . . .	Sicily, ...	1739 + 86; 1741; 1823.	89
VAL DI DIANO, . .	. . . . .	1559, very violent.	1
VAL D' ELSA, . . .	Tuscany, ...	1848.	1
VALDIERI, . . .	Piedmontese Alps, . .	1882.	1
VAL D' ILLIÈRES, opposite	Bex, ...	1853 + 1 E.–W.; 1869 + 1; 1881.	3
VAL DEL MAZZARA, .	Sicily, ...	1841 S.–N.	1
VAL DI NOTO, . .	Sicily, ...	1741; 1790; *1818* + 1; 1823.	5
VAL DI PIERLA, . near	Corlona, Tuscany, . .	1865 + 13.	14
VAL DI RENDEYA, .	Tyrol, ...	1851 + 5.	6
VAL DE TRAVERS, .	. . . . .	1831 + 1; 1852.	3
VALDOBBIANO, . .	Treviso Province, . .	1859 E.–W.; 1860.	2
VALENÇA DO MINHO, .	Portugal, ...	1856 + 2.	3
VALENCE, . . .	Drôme, ...	1847 E.–W.; 1867 E.–W., felt all along the axis of the Valley of the Isère; 1855 E.–W. + 1; 1881.	5
VALENCIA PROVINCE, .	Spain, ...	1395 + 3; 1828 + 3.	8
VALENCIA, . . .	Spain, ...	1395; 1747 + 1; 1823; 1828 + 3; 1867 E.–W. + 3; 1829 + 8.	21
VALENTINO, . . .	Italy, ...	1395.	1
VALENZA, . . .	Allessandria, . . .	1881.	1
VALESIA, ...	North Italy, . . .	1880 + 1.	2
VALLA DER WILDSCHONEN,	Near Wörgel, Austria, .	1863 S.–E.	1
VALLE DI CAPRINO, .	. . . . .	1880.	1
VALLE MAGGIO, . .	. . . . .	1870 W.N.W.–E.S.E.	1
VALLENDAR, . . .	Coblentz C., Rh. Prussia, .	(1869 + 4) N.W.–S.E.	5
VALLOIRE, . . .	Maurienne, ...	1844.	1
VALMONTANA, . .	. . . . .	1754.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
VALONA = AULONA, .	Albania, ...	1851; 1855 + 1 S.E.–N.W.; (1856 + 3) E.–W. + 3 + 2 W.–N.W.; 1857 + 5; 1858 E.–W. + 29 + 1, very violent, + 1 S.E.–N.W., very violent; 1859 + 1; 1860 + 4 + 3 S.E.–N.W.; 1862 + 3; 1866 + 3 + 33 S.–N.; 1868 + 1 + 1 N.–S.; 1869 + 6; 1871 N.E.–S.W. + 4.	116
VALRÉAS, . . .	Vaucluse, ...	1773; 1835.	2
VAL SESIA, . . .	Piedmont, ...	1880 S.–N. + 2.	3
VALTELINE, The, . .	. . . . .	1618; 1623.	2
VAL VACCARA di Monte	Baldo, ...	1880.	1
VAL VARZO, . . .	Upper Italy, . . .	1880 S.–N.	1
VAMOS, ...	Hungary, ...	1829 + 6.	7
VAN, ...	Armenia, ...	1871; 1881, 34 villages E. of Van destroyed.	2
VANDELLOS, . . .	Cataluña, ...	1845 + 1.	2
VANKA DEFILE, . .	Caucasus, ...	1867 + 1.	2
VANNES, ...	. . . . .	1286; 1854.	2
VANOZ, ...	Jura, ...	1857.	1
VAR Department, . .	. . . . .	1818.	1
VARALLO, . . .	Val Sessia, ...	1864 + 2; 1871; 1881 + 3.	8
VARNA, ...	Turkey, ...	1802; 1856; 1858 N.–S., R. = 100 km., + 1; 1875.	5
VARNILA Valley, . .	Italy, ...	1874 + 2.	3
VASTO, ...	Abruzzi, ...	1857.	1
VAUCLUSE, . . .	. . . . .	1812; 1863.	2
VAUDREVANGE, . .	Rhine Valley, . . .	1846.	1
VAUDS (Pays de), . .	. . . . .	1577 + 1; 1618; 1729; 1737; 1847 + 3; 1877; 1879; 1881 + 3.	15
VAUMARCUS, . . .	Neuchatel Canton, . .	(1842 + 1) S.–N.	2
VAURENS, . . .	Vaud Canton, . . .	1846.	1
VAUVERT, . . .	Gard, ...	1836.	1
VEDONO, ...	Caucasus, ...	1854.	1
VEGLIA, . . . near	Trieste, ...	1649 + 6; 1857 S.–N.; 1870 + 2.	11
VEGLIATURI, . . .	Calabria, ...	1870; 1871.	2
VEIS-AGHA, . . .	Messenia, Greece, . .	1846.	1
VELDES, ...	Carniola, ...	1879; (1882 + 3) S.–N.	5
VELESVER, . . .	Croatia, ...	(1876 + 1) S.E.–N.W.	2
VELEZ-MALAGA, . .	Spain, ...	*1804* N.–S.	1
VELICA, ...	Albania, ...	1866 + 5.	6
VELLETRI, . . .	. . . . .	1729; 1752 + 1; 1771; *1785*; 1801; 1837 + 3; 1885 + 2; 1869; 1870 + 1; (1873 + 3) S.E.–N.W.; 1880 + 1; 1881 + 5; 1882 + 8.	37

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
VELSBERG, . . .	Tyrol, ...	1862.	1
VELTLEN, . . .	Southern Alps, . . .	1882.	1
VENARRANO, . . .	Tuscany, ...	1846.	1
VENCE, ...	Var, ...	*1818* + 3 ; 1843.	5
VÉNDÉE, Depmt. de la, .	. . . . .	1877 + 1.	2
VENDÔME, ...	Loire et Cher, . . .	1864, extended to the S.E. to Champigny, and N.E. to Ouques ; 1866 + 1.	3
VENICE, ...	. . . . .	1096 ; 1105 ; 1212 ; 1278 ; 1282 ; 1301 ; 1343 + 15 ; 1345 + 15 (shocks lasted 15 days) ; 1348 ; 1365 ; 1373 ; 1410 ; 1503 ; 1510 ; 1511 ; 1570 + 84 ; 1636 ; 1661 ; **1667** + 1 ; 1670 ; 1688 + 4 ; 1691 ; 1693 ; 1697 + 2 ; 1703 ; 1711 ; 1719 + 3 ; 1722 ; 1725 + 1 ; 1747 ; 1750 ; 1751 ; 1754 ; 1756 + 3 + 1 s.e.–n.w. ; 1767 ; 1776 ; 1781 ; 1783 ; 1785 + 3 ; 1786 ; 1787 + 3 ; 1788 ; 1810 ; 1819 ; 1822 + 1 ; 1826 + 1 ; 1827 + 2 ; 1828 + 1 ; (1831 + 2) e.–w. ; 1834 ; 1836 e.–w. + 1 n.e.–s.w. + 2 n.–s. + 1 e.–w. ; (1838 + 2) e.–w. ; 1840 s.–n. ; 1843 + 1 ; 1845 + 1 ; 1851 s.–n. ; 1855 ; 1857, extended to Treviso, Pieve di Soligo, and Valdobbiadene. Mr. Berti points out that this shock and the two preceding ones have their centres on a line parallel to one of the great axes of upheaval of the Alps) ; 1859 n.–s. + 1 e.–n.e., very violent at Colalto, Folze, Pieve di Soligo, Schraglia, Moriago, Col de San Martino, Guja, Combai, Miane, St. Pietro, and extended even into the Valdobbiano and Vidor—limits, N. Auro-zono, W. Trente, and Verona, S. southern bank of Po, E. Trieste ; 1857 + 1 n.e.–s.w. + 1 e.s.e.–n.n.w. + 1 e.–w. ; 1859 n.–s. + 1 e.n.e.–w.s.w., limits—N. Auzonzo, W. Trente and Verona, S. right bank of Po, E. Trieste, + 1 ; (1860 + 2) e.–w. ; 1861 ; (1862 + 1) s.–n. ; 1865 ; 1870 + 7 + 1 s.s.e.–n.n.w. ; 1872 w.–e. ; 1873 + 1 ; 1880 ; 1881 ; 1882 n.e.–s.w.	239
VENETIAN TERRITORY,	. . . . .	1695 + 3.	4
VENOSA, . . .	Basilicata, ...	1851 + 1 ; 1852 + 1 ; 1853 + 2 ; 1854 ; 1855.	9
VENTA de los Cazadores,	Andalucia, ...	1863 + 2.	3
VENTILONE, . . .	Neapolitan Kingdom, . .	1856.	1
VERA, ...	Andalucia, ...	1860 + 1 ; 1863 s.–n. + 56 ; 1864.	60
VERCELLI, . . .	. . . . .	1828 + 1 ; 1880 + 1.	4
VERCHANGARSKOI, .	9 versts from Irkutsh, . .	1771 + 1.	2
VERDUN, ...	. . . . .	1783.	1
VERFEIL, . . .	Haute Garonne, . . .	1854.	1
VERGAGLIA, . . .	19 km. from Sienna, . .	1871.	1
VERGATI, . . .	Bologna, ...	1864 + 14.	15
VERKOTEMSK, . .	Wologda Gov., Russia, .	1829 + 2.	3
VERMUGNAGNA, . .	Piedmont, ...	1849.	1
VERNANTE, . . .	,, ...	1849.	1
VERNAUD CANTON, .	Aisne, ...	1873 + 1.	2
VEROLI, ...	Frosinone, Italy, . .	1777.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
VERONA,		1184; 1187; 1334; 1365 + 1; 1703; 1756 + 1; 1810; 1811 + 3; 1828 + 1; 1832 + 3; 1845; 1851 + 1 E.–W.; 1853 + 2; 1868 N.N.E.–S.S.W.; 1869 E.–W. + 1; 1870 + 1; 1871; 1873 + 1; 1880, extended N. to Etschi Valley, and S. to Volpicella, + 1 E.–W.; 1881 + 6; 1882.	43
VERPILLÈRE, La,	Isère,	1761.	1
VERRA = VERA,	Navarra, Spain,	1853.	1
VERSAILLES,		1756 + 1; 1760 + 1; 1769.	5
VERS, sous Sillières,	Jura,	1849.	1
VERVIERS,	Belgium,	1828 + 1; 1873; 1881, the earthquake seemed to proceed from the Coal Fields of Belgium, and to extend to the Rhine from Verl to Mayence, to Tournai in the W. and Marburg in the E.	4
VERZUNO,	Emilia,	1881.	1
VERZUOLO,	Piedmont,	(1878 + 1) E.–W.	2
VESOUL,		1682; (1780 + 1) E.–W.; 1855 + 3; 1881.	8
VESUVIUS,		1682; 1694 + 6; 1698; 1707; 1174; 1732; 1758 + 1; 1760 + 10; 1766 + 3; 1767 + 1; 1779; 1784; 1787; 1794 + 3; 1804; 1805; 1806; 1816; 1822; 1828 + 1; 1830; 1831 + 1; 1832; 1833; 1834 + 1; 1835 + 1; 1845; 1847; 1848; 1853; 1855 + 1; 1856; 1857; 1858; 1859 + 6; 1861, emission of gases CO^2 59·5 per cent., N and carburetted hydrogen 40·5 per cent. (St. Clair Deville), + 2 + 35 S.E.–N.W.; 1862 + 16; 1863 + 24; 1864 + 4; 1865 + 86 + 1 N.W.–S.E.; 1866 + 25; 1867 + 67; 1868 + 28; 1869 + 107 + 4 E.–W. + 2 N.E.–S.W. + 1 N.–S.; 1870 + 58; 1871 + 23, during a certain period continuous, + 7; 1874 + 19; 1878 + 8; 1879 + 4; 1880, extended to Ischia, + 4; 1881 + 5.	605
VEVEY,	Switzerland,	1650; 1729; 1747 + 1; 1848 S.E.–N.W.; 1851; 1855 S.–N.; 1877; 1879; 1881 + 2.	12
VEYRE,	Puy de Dôme,	1880 E.–W.	1
VEZELAY,	Yonne,	1760 + 1.	2
VEZIERS,	Aveyron,	1876.	1
VESZPRENI COM.,	Hungary,	1880.	1
VIA GRANDE,	Sicily,	1868.	1
VIANA = VIANNA,	Minho, Portugal,	1757; 1857; 1866 W.–E.	3
VIBONATI,	Calabria Citra,	1858 + 5.	6
VIC,	Meurthe,	1846.	1
VICALI,	Abruzzi,	1842.	1
VICARELLO,	Pisa, Italy,	1846.	1
VICCHIO,	Mugello,	1835, very violent.	1
VICDESSOS,	Ariège,	1852.	1
VICENZA,		1242; **1373 + 1**; **1376 + 8**; 1385; 1833 + 1; 1855 + 1; 1859 E.–W.; 1864 N.E.–S.W.; 1867 S.–E.; 1869 N.E.–S.W; 1870; 1882.	23

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
VICHELY, . . .	Semplin Com., Hungary, .	1787.	1
VICHY LES BAINES, . .	Allier, ...	1857 + 1 N.–S.	2
VICKRATHSBERG, . .	Gladbach, Rhenish Prussia,	1881.	1
VICO, ...	Corsica, ...	*1775* + 5 S.E.–S.W.	6
VICO, ...	Capitanata, ...	1694.	1
VICO SOPRANO, . .	Grisons, ...	1880.	1
VIDOR, . . . on	Piave, Treviso Province, .	1859.	1
VIÉGE, OR VISP, . .	Switzerland, . . .	1755 ; 1855 + 4, series of shocks commencing July 25th, about 50, 26th, 25 sh., 27th, 27 sh., 28th, 3 sh., 29th, 28 sh., 30th, 13 sh., 31st, 5 sh. ; August 1st, 1 sh., 2nd, 4 sh., 3rd, 3 sh., 4th, 1 sh., 5th, 2 sh., 7th, 6 sh., 8th, 4 sh., 9th, 1 sh., 11th, 5 sh., 12th, 7 sh., 13th, 4 sh., 14th, 6 sh., 15th, 3 sh., 16th, 2 sh., 17th, 6 sh., 18th, 3 sh., 19th, 18 sh., 20th, 3 sh., 21st, 3 sh., 22nd 7 sh., 24th, 5 sh., 25th, 1 sh., 26th, 3 sh., 27th, 4 sh., 28th, 1 sh., 29th, 6 sh., 30th, 1 sh., 31st, 1 sh. ; September 1, 1 sh., 3rd, 4 sh., 4th, 1 sh., 5th, 2 sh., 6th, 3 sh., 11th, 1 sh., 12th, 3 sh., 13th to 16th, 12 sh., 17th, 3 sh., 18th, 4 sh., 21st, 2 sh., 22nd, 1 sh., 23rd, 3 sh., 25th, 6 sh., 26th, 2 sh., 27th, 2 sh., 28th, 2 sh., 29th, 2 sh., 39th, 1 sh. ; October 1st, 2 sh., 3rd, 1 sh., 6th, 3 sh., 7th, 1 sh., 10th, 4 sh., 12th, 4 sh., 14th, 1 sh., 15th, 3 sh., 17th, 2 sh., 18th, 2 sh., 19th, 2 sh., 20th, 3 sh., 25th, 2 sh., 28th, 33 sh., 29th, 10 sh., 31st, 1 sh. ; November 2nd, 1 sh., 3rd, 2 sh., 7th, 1 sh., 12th, 3 sh. ; December 15th, 1 sh., 17th, 1 sh., 27th, 2 sh., 31st, 1 sh ; 1856 + 6 + 1 S.W.–N.E. ; May 3, 1 sh. ; 1857 ; 1858 ; 1862 ; 1863 ; 1867 ; 1869—the directions of the undulations constantly the same, extended from Weisshorn to Interlacken, the village of Coerbel the centre ; 1880 ; 1881 + 1.	430
VIEL, ...	Half a league from Barrège,	1784.	1
VIEILLE VILLE LES BAINS,	Yvetot Arondissement, .	1845 E.–W.	1
VIELLE SEGURE, . .	Pyrénées, ...	1817.	1
VIEL SALM, . . .	Luxemburg, Belgium, . .	1867.	1
VIENNA, ...	. . . . .	1201 ; 1267 ; 1348 ; 1442 ; 1468 ; 1560 ; 1590 + 2, acted along a line 40 miles long N.–W. of Vienna, parallel to the Danube ; 1654 ; 1679 ; 1711 ; 1712 ; 1749 + 2 ; 1760 ; 1763 + 1 ; 1766, also felt at Pressburg, + 2 ; 1768 N.E.–S.W. + 2 ; 1774 N.W.–S.W. + 2 ; 1779 ; 1783 + 1 ; 1784 ; 1794 ; 1807 ; 1810 + 1 ; 1811 ; 1837 N.W.–S.E. + 1 ; 1841 N.–S. ; 1843 ; 1846 ; 1849 ; 1852 ; 1856 ; 1857 ; 1858 + 4 ; 1860 ; 1862 ; 1863 ; 1865 + 1 ; 1873 ; (1876 + 2) N.E.–S.W., extended over a wide area—Lower Austria and Moravia, neighbouring part of Styria, Upper Austria, Bohemia, to Prague and Hungary, limits—N. Wittingau, Schilletau, Budweiss, Trebitsch, Tischlowitz, and Prerau, S. Œndenburg, Kindberg, and Northern Alps ; 1880.	64
VIENNE, ...	Isère, ...	465 ; 1782 ; 1814.	3
VIERSEN, . . .	Rhenish Prussia, . . .	1869.	1
VIETRI, ...	Principato, ...	1684.	1
VIGGIANO, . . .	Basilicata, ...	1853 ; 1857, very violent, + 6 ; 1858 + 1.	10
VIGNANO = VIGAUN, near	Radmansdorf, Carniola, .	1870 + 1 E.–W.	2
VILBEL, ...	Cassel, S.W. Germany, .	1869 + 1.	2

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
VILBEL Niederölstadt, .	Darmstadt, . . .	1869.	1
VILICH, ...	Bonn C., Rh. Prussia, .	1869 E.–W.	1
VILLACH, . . .	Carinthia, ...	1848 ; (1855 + 1) E.–W. + 2 + 3 W.–E. ; 1863 ; 1879 ; (1881 + 5) S.–N. ; 1882.	17
VILLA D'ANCARNO, near	Norcia, ...	1859 + 2.	3
VILLA DI ST. ANGELO,	. . . . .	1859 + 2.	3
VILLA FRANCA, . near	Lisbon, ...	1858 + 1.	2
VILLAJOSA, . . .	Valencia, ...	1829 + 1.	2
VILLA NOVELLA, . .	Piedmont, ...	1878 E.–W.	1
VILLANUOVA, . . .	Algarbia, Portugal, . .	1719 ; 1722.	2
VILLANY, . . .	Hungary, ...	1876.	1
VILLA PRATI, . .	Romagna, ...	1881.	1
VILLA QUIETE, . .	Bologna, ...	1881.	1
VILLAR, ...	Auch, Gers, . . .	(1775 + 2) E.–W.	3
VILLAR, ...	Savoie, ...	1808.	1
VILLARS BOCAGE, . .	Calvados, ...	1861.	1
VILLEFRANCHE, . .	Rhône, ...	1855 + 2 ; 1859 + 1.	5
VILLEFRANCHE, . .	Haute Garonne, . . .	1854.	1
VILLENEUVE, . .	Vaud Canton, . . .	1835 ; 1851 ; 1853 ; 1877 ; 1880 ; 1881 + 1.	7
VILLERTREUX, . .	Loire et Cher, . . .	1864 + 1.	2
VILLETTE, . . .	Maurienne, ...	1847.	1
VILLGRATEN, . . .	Pustherthal, Tyrol, . .	1879 N.W.–S.E.	1
VILMAR-AUMERAU, .	Lahn Valley, . . .	1869 W.–E.	1
VILMINORE, . . .	Seriana Valley, . . .	1882.	1
VILS, ...	Tyrol, ...	(1882 + 4) W.–E.	5
VINADERS, . . .	Tyrol, ...	1878.	1
VINKOVEZE, . . .	Sclavonia, ...	1859 S.W.	1
VINTEMILLE, . . .	Bouches du Rhône, . .	1854.	1
VINTEMILLE, . . .	Milan, ...	1861 + 1.	2
VINTIMIGLIA, . .	Genoa Province, . .	1831.	1
VIRBAZAR, . . .	Montenegro, . . .	1880 + 2.	3
VIRÉ, ...	Calvados, ...	1853, extended to Laval.	1
VIRGINMOST, . . .	Illyria, ...	1870.	1
VIRNEBURG, . . .	Adenau C., Rhenish Prussia,	1869.	1
VIRSA, ...	Spoleto, Italy, . . .	1730 + 3.	4
VISEU, ...	Portugal, ...	1858 + 1.	2
VISNYOVE = Vissenyove,	Near Sillein, Hungary, .	1858, January, 6 sh., 16th, 12 sh., 17th 8 sh., + 23 + 1 + 8 + 1 S.E.–N.W. + 2 ; 1864.	62
VISONE, ...	Belluno Territory, . .	1873.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
VISP TERMININ, . .	. . . . .	1855.	1
VITERBO, ...	. . . . .	1695; 1719; 1740 + 3; 1755 + 2; *1819 + 1*; 1881 + 1 + 1 S.E.–N.W.	14
VITRÉ, ...	Ille et Vilaine, . . .	1805; 1853.	2
VITRY, ...	Aube, ...	1829.	1
VITTEAUX, . . .	Côte d'Or, ...	1866.	1
VITTORIA, . . .	Belluno Territory, . .	1873 + 1.	2
VITZNAU, . . near	The Rhigi, ...	1879; 1881 N.E.–S.W.	2
VIVIERS, ...	Ardèche, ...	1773; 1873 + 1.	3
VIVAJO, ...	Tuscany, ...	1846.	1
VIVONNE, . . .	Vienne, ...	1779; 1869 + 2.	4
VIZILLE, ...	Isère, ...	1837; 1861 + 1.	3
VIZZINI, ...	Catania, Sicily, . . .	1870.	1
VLAARDINGEN, . .	South Holland, . . .	1803.	1
VÖCLABRUCK, . .	Traun Circle, Austria, . .	1826.	1
VOESLAU, . . near	Baden, Vienna, . . .	1863; 1870.	2
VOGELSBERG, . . .	Darmstadt, ...	1869.	1
VOGHERA, . . .	. . . . .	1828 + 1, the limits of the earthquake which lasted 3 days, were Marseilles, and a curve joining Vercelli, Voghera, and Genoa.	2
VOGHESE, . . .	Piedmont, ...	1824.	1
VOIGBERG MINE, . .	Saxony, ...	1860.	1
VOIGTLAND, . . .	. . . . .	1701 + 2; 1720; 1770 + 3; 1786; 1840; 1860; 1862 + 1, extended to Leipzig, + 2 S.E.–N.W. + 1; 1875 + 1.	18
VOITSBERG, . . .	Saxony, ...	1860 N.E.–S.W.; 1861 S.W.–N.E.	2
VOLCANO ISLAND, .	. . . . .	1717; 1771.	2
VOLHYNIA, . . .	. . . . .	1790.	1
VOLO, ...	Thessaly, ...	1864 + 19 + 2 S.–N.; 1865 + 2; 1867; 1868 + 6; (1876 + 3) W.–E.; 1882 + 2.	40
VOLONNE, . . .	Basses Alpes, . . .	1866.	1
VOLOSCA, . . .	Istria, Austria, . . .	1869; 1870 + 22 + 5 E.–W. + 1, violent, + 51; 1881 + 1 N.–S.	83
VOLPERTSHASEN, . .	Lahn Valley, . . .	1869 + 5.	6
VOLPICELLA, . . .	. . . . .	1880.	1
VOLPIGLIANO, . .	Parma Territory, . .	1882.	1
VOLTERRA, . . .	. . . . .	1834 + 6; 1843; 1846 + 4; 1853 + 1; 1867; 1869 + 3.	20
VORARLBERG, . .	. . . . .	1881.	1
VORAU, ...	Styria, ...	1865.	1
VORDERSTODER, . .	Bohemia, ...	1856 + 1.	2
VORFELDEN, . . .	Rhine Valley, . . .	1869.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
VOREPPE, . . .	Isère, ...	(1753 + 1) N.–S.	2
VOSGES DEPARTMENT,	. . . . .	1843 ; 1851.	2
VOSS, ...	Norway, ...	*1819* + 4 ; (1824 + 4) W.–E.	10
VOSTEZZA, . . .	Doris, Greece, . . .	*1817* + 8 ; 1850 ; 1860.	11
VOUVRY, ...	Switzerland, . . .	1880.	1
VRAIGNES, . . .	Somme, ...	1873,	1
VROLA, ...	Russian Lapland, . .	1819.	1
VSINGEN, ...	. . . . .	1846 + 3.	4
VULCANO ISLAND, .	*See* Volcano Island, . .		
VULPERA, . . .	Engadine, ...	1879.	1
VULTUR VOLCANO, .	Basilicata, ...	1851.	1
WADEBRIDGE, . .	Cornwall, ...	1860.	8
WADENSCHWYL, . .	Zurich Canton, . . .	1826 ; (1858 + 1) E.–W. ; 1861 ; 1862 ; 1865.	6
WADSTENA, . . .	Gothland, ...	1847.	1
WAGSTADT, . . .	Moravia, ...	1827 ; 1879.	2
WAHLSCHIED, . .	Sieg. C., Rh. Pussia, . .	1869 + 2.	3
WAISENHAUS, . near	Masons, Grisons, . .	1874.	1
WAITZEN, . . .	Hungary, ...	1852 + 1.	2
WALD, ...	Rudolph's Railway, Styria, .	1877 + 2.	3
WALDALGESHEIM, .	Rhine Valley, . . .	1869 + 2.	3
WALDBREITBACH, .	Neuwied C., Rh. Prussia, .	1869 W.–E. + 3 + 1 W.–E.	5
WALDBROEL, . . .	Rhenish Prussia, . .	1869 W.–E.	1
WALDENBOURG, . .	Bâle, Environs of, . .	1870 ; 1881.	2
WALDENBURG, . .	Saxony, ...	1880 + 1 ; 1881.	2
WALDHEIM, . . .	Saxony, ...	1830.	1
WALDKIRCH, . . .	Baden, S.W. Germany, .	1879.	1
WALDMÜNCHEN, . .	Bavaria, ...	1858.	1
WALDORF, . . .	Bonn C., Rh. Prussia, . .	1856.	1
WALDSCHACH HERRSCHAFT,	Styria, ...	1880 N.E.–S.W. + 1.	2
WALDSCHUT, . . .	Baden, ...	1878 ; 1881 + 1.	3
WALDSEE, . . .	Würtemberg, . . .	1861.	1
WALD-ÜLVERSHEIM, .	Rhenish Hesse, Darmstadt, .	1869 + 2, the surface shaken elliptical in form, the greater axis 50 km. long, extended from Ensheim in the W. to Rerchelsheim in the E. ; the lesser axis, 40 km. long, extended from Philippseich in the N. to Rodau in the S.	3
WALES, ...	. . . . .	1274 ; 1780 ; 1852 ; 1863 ; 1868 ; 1869.	6
WALES, NORTHERN, . .	. . . . .	1780 ; 1827 ; 1842.	3
WALLA, ...	Wudsto Dis., Sweden, .	1858.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
WALLACHIA, . . .	. . . . .	1802 + 1 ; 1838 + 4 ; 1879.	8
WALSERTHAL, . .	Tyrol, ...	1881.	1
WANGEN IN ALLGAU, .	Würtemberg, . . .	1830 ; 1861.	2
WANGAN ON AAR, .	Berne Canton, . . .	1853 ; 1855 S.–N. + 1 ; 1856 S.–N. + 3 S.W.–N.E.	7
WANSFORD, . . .	. . . . .	1844.	1
WARASDIN, . . .	Croatia, ...	1812 + 1 ; 1880 S.–N.	3
WARASDIN DISTRICT,	,, ...	*1603* ; **1614** + *1* ; 1880.	4
WARE, ...	. . . . .	1750.	1
WARSAW, ...	. . . . .	1802.	1
WARTMANNSTOETTEN,	Lower Austria, . . .	1876.	1
WARTSBERG, . . .	Upper Austria, . . .	1868 + 1 ; 1869 + 1.	4
WARWICK, . . .	. . . . .	1750, extended from Warwick to Bury St. Edmonds, and from Lincoln to Northampton) + 3.	4
WASSENNACH, . .	Rhine Valley, . . .	1869.	1
WASTIN, . . . near	Jassy, Roumania, . .	1880.	1
WATERLOO, . . near	Liverpool, ...	1868.	1
WATERFOOT, . . .	. . . . .	1869.	1
WATLINGTON, . .	Oxford, ...	1683.	1
WATSBORG, . . .	Carinthia, ...	(1813 + 3) N.W.–S.E.	4
WATTISFIELD, . .	Suffolk, ...	1859.	1
WECHSEL, . . .	Austria, ...	1881.	1
WECHSELBURG, . .	Upper Saxony, . . .	1821, line from this to Pennig most strongly shaken.	1
WECKSELDORF, . .	Bohemia, ...	1882 S.W.–N.E.	1
WEDEN FORTRESS, .	Lat. 42° 57′, Long. 63° 48′, [from Is. of Ferro], Caucasus,	1862 + 2 ; 1864 N.W.–S.E. ; 1865.	5
WEGHEL, . . .	Limbourg, ...	1843 + 1.	2
WEHR, ...	Baden, S.W. Germany, .	1869 + 2.	3
WEICHSELBODEN, .	Styria, ...	1876 ; 1880 + 1.	3
WEIDEN, . . . near	Aachen, Rhenish Prussia, .	1873 + 2.	3
WEIDENTHAL, . .	Bavaria, ...	1869.	1
WEILBACH, . . .	Bavaria, ...	1850.	1
WEILBECK, . . .	Nassau, ...	1850.	1
WEILBURG, . . .	Nassau, ...	(1869 + 1) W.–E. + 2.	4
WEIMAR, . . .	. . . . .	1720 ; 1785 ; 1847 ; 1872 + 2.	6
WEINGARTEN, . .	Baden, ...	1873 ; 1880.	2
WEINSIEDEL DISTRICT,	Fichtelgebirge, Bohemian [Frontier,	1824 + 8.	9
WEISCHLITZ, . . near	Plauen, Saxony, . . .	1880.	1
WEISSBRIACH, . .	Carinthia, ...	1855 + 2 ; 1857 ; 1881 N.W.–S.E.	5
WEISSENBACH, . .	Lower Austria, . . .	1873.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
WEISSENFELS, . .	Carniola, ...	1855 W.–E. ; 1876.	2
WEISSKIRCHEN, . near	Temeswar, Lower Danube, .	1879 + 20 ; 1881 + 1 ; 1882 E.–W.	24
WEITERSTADT, . near	Darmstadt, ...	1869 + 8.	9
WEITSCH, . . .	Murzthal, Styria, . .	1857 + 1 ; 1865.	3
WEIXELBURG, . .	Carniola, ...	1882.	1
WELJAMINOUSK, . .	Caucasus, ...	1870.	1
WELLENBURGH, . .	Bâle C., ...	1721.	1
WELMICH, . . .	Rheingau C., Rh. Prussia, .	1869.	1
WELLS, ...	. . . . .	1248, cathedral injured ; 1852 + 1.	3
WELSH NEUREUTH, .	Rhine Valley, . . .	1880.	1
WEND, ...	Shropshire, ...	1863.	1
WENLOCK, . . .	. . . . .	1789 ; 1820 ; 1821.	3
WENLOCK HEAD, . .	. . . . .	1828.	1
WERDER, . . .	Brandenburg, Prussia, .	(1876 + 1) S.W.–N.E.	2
WERKNEOUDINSK, .	S.E. of Lake Baikal, . .	1864 + 1 ; 1866 + 1.	4
WERLINGEN, . . .	Sweden, ...	1850.	1
WERRA RIVER, Banks of,	Cassel, ...	1767.	1
WERSEN, . . near	Saltzbourg, Tyrol, . .	1841.	1
WESCHNITZTHAL, .	Darmstadt, ...	1877.	1
WESEL, ...	Rhenish Prussia, . . .	1877 ; 1881 S.W.–N.E.	2
WESSERLING, . .	Haut Rhin, . . .	1855 E.–W.	1
WESTBURY ON FRYNN,	. . . . .	1852.	1
WESTERBURG, . .	Nassau, ...	1869 + 1.	2
WESTERHŒS, . .	Sweden, ...	1823.	1
WESTERWALD, The, .	Westphalia, Prussia, . .	1869 + 1.	1
WESTMORELAND, . .	. . . . .	1651 ; 1817.	2
WESTNORDLAND, . .	Sweden, ...	1762.	1
WESTON-SUPER-MARE,	. . . . .	1863 ; 1869.	2
WESTPHALIA, . .	. . . . .	1612 ; 1640 ; 1641 ; 1681.	4
WESTROBOTHNIA, .	Sweden, ...	1763 + 12.	13
WESTROGOTHA, . .	Sweden, ...	1858.	1
WETTERAU DISTRICT,	Darmstadt, ...	1869.	1
WETTERN, . . .	Rheingau C., Rh. Prussia, .	1869.	1
WETTERSEE (between it and Ostsee), Sweden, . .		1879.	1
WETZLAR, . . .	Rhenish Prussia, . .	1756; 1780+1; 1855; 1869 S.W.–N.E. + 7 + 1 W.–E.	13
WEXFORD, . . .	. . . . .	1762 ; 1863.	2
WEYER, ...	Limbourg, Belgium, . .	1869 + 1.	2
WEYERBUSCH, . .	Sieg Valley, . . .	1869.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
WEYMOUTH,		1853.	1
WHEAL ELDON,		1859.	1
WHITCHURCH,	Shropshire,	1863.	1
WHITEHAVEN,		1755; 1780; 1786 + 1.	4
WHITE SEA,	Coast of,	1758.	1
WICKERT, / WICKLER,	Nassau,	1850; 1869 + 1.	3
WICKLOW,		1760.	1
WICTING,	Glanthal, Carinthia,	1825.	1
WIDDEN = WIDEN,	Bulgaria,	1802.	1
WIDDEN,	Land's End,	1860.	1
WIDDICOMBE,	Dartmoor,	1752.	1
WIEHL,	Gummersbach C., Rh. Prussia,	1869.	1
WIENWALD,	Austria,	1875.	1
WIESBADEN,	Nassau,	1857; 1858; 1860 + 1; 1868 + 1; 1869 + 12; 1871; 1872; 1878 + 1 + 3 S.E.–N.W.; 1880.	27
WIESEBURGH = Mozsony,	Hungary,	1873 + 1.	2
WIESENTHAL,	Saxony,	1881.	1
WIGHT, ISLE OF,		1750; 1863.	2
WILLDBACH,	Saxon Voigtland,	1862.	1
WILDBAD GASTEIN,	Tyrol,	1862.	1
WILDSCHÜTZ,	Saltzbourg, Austria,	1878.	1
WILDSCHÖNAU, near	Wörgl, Tyrol,	1865 S.E.–N.W.	1
WILDUNGEN,	Waldeck, S.W. Germany,	1856.	1
WILLICH,	Bonn C., Rhenish Prussia,	1856.	1
WILRÉ,	Rhine Valley,	1873.	1
WILSBERG,	Tyrol,	1862 + 1.	2
WILTEN,	Tyrol,	1862 + 2 S.E.–N.W. + 2 N.W.–S.E.	5
WILTSHIRE,		1764.	1
WINBOURNE,		1750.	1
WINDESHEIM,	Overyssel, Netherlands,	1869.	1
WINDISH-GARSTEN,	Upper Austria,	1857 E.–W. + 4.	5
WINDISH-GROETZ,	Styria,	1869 N.–S. + 1.	2
WINDISH KAPELLEN,	Upper Austria,	1856.	1
WINDISH LANDSBERG,	Styria,	1877.	1
WINDISH MATREY,	Tyrol,	1862 + 4; 1865 N.–S.; 1867 + 3.	10
WINDISK MARKTEL,		1556.	1
WINDSCHACHT,	Hungary,	1854.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
WINGER, ...	Norway, ...	1773.	1
WINNENDEN, . . .	Würtemberg, . . .	1861 + 1.	2
WINNENGEN, . . .	Rhenish Prussia, . .	1869.	1
WINTERBURG, . .	Creuznach C., R. Prussia, .	1869.	1
WINTERTHUR, . .	Zurich C., Switzerland, .	1557 ; 1826 ; . 1861.	3
WIPPTHAL, ...	Tyrol, ...	1878 + 1.	2
WISINNEPOLJE, . .	Uman C., Russia, . .	1880.	1
WISMAR, ...	Baltic Sea, ...	1683.	1
WISSEN, ...	Altenkirchen C., Rh. Prussia,	1869 + 4.	5
WISSEMBOURG, . .	Bas Rhin, ...	1802 ; 1869 S.W.–N.E.	2
WISSENBACH, . .	. . . . .	1869.	1
WITCHBACH, . . .	Aix la Chapelle, . . .	1818 + 2.	3
WITTEN, ...	Westphalia, . . .	1873 + 1 ; 1879 N.–S.	3
WITTENGAU SCHLOSS,	Bohemia, ...	1877.	1
WITTENGAU, . . .	Bohemia, ...	1876.	1
WITTLICH, . . .	Rhenish Prussia, . .	1846 + 2 ; 1869.	4
WLADIKAWKAS, . .	90 miles N. of Tiflis, . .	1874 S.W.–N.E.	1
WOHLHAUSEN, . .	Lucerne, ...	1871.	1
WOLDSDORF = WOHLSDORF,	Weimar, . . .	1869.	1
WOLFSKEHLIN, . .	Rhine Valley, . . .	1869 + 2.	3
WOLFSKELLER, . .	Rhine Valley, . . .	1869.	1
WOLLIGEN, . . near	Villach, Carinthia, . .	1867 N.–S. + 3.	4
WOLOGDA, . . .	North Russia, . . .	1829 + 2.	3
WOLVERHAMPTON, .	. . . . .	1677 ; 1678 ; 1863.	3
WOODHOUSE, . . .	. . . . .	1871.	1
WOODHOUSE EAVES, .	Charnwood Forest, .	1831.	1
WORCESTER, . . .	. . . . .	287 ; 1048 ; 1574 ; 1768 ; 1863 ; 1868 + 1.	7
WORCESTERSHIRE, .	. . . . .	1868.	1
WÖRDL, ...	Carniola, ...	1871 + 4.	5
WORDSLEY, . . .	Worcestershire . . .	1863.	1
WORKINGTON, . .	. . . . .	1786.	1
WORMS, ...	. . . . .	838 ; 855 ; 1642 + 3 ; 1728 ; 1776 ; (1869 + 5) S.S.W.–N.N.E. ; 1872 + 2 ; 1873.	18
WORONEJSKAJA, . .	Kauban R., Caucasus, . .	1865.	1
WORRINGEN, . . .	Cologne C., Rhenish Prussia,	1869 N.–S.	1
WÖRTH, ...	Bavaria, ...	1880.	1
WORTH PARISH, . .	Sussex, ...	1758.	1
WORTHING, . . .	. . . . .	1871 + 2.	3

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
WRANOW, . . .	Hungary, ...	1778 + 11.	12
WREXHAM, . . .	. . . . .	1750.	1
WRUITA VALLEY, . .	Piedmont, ...	1808.	1
WUNDSCHAH, . .	Styria, ...	1870 ; 1871.	2
WURM, ...	Baden, ...	1873 ; 1874 + 1 N.–S.	3
WÜRMLACH, . . .	Carinthia, ...	1869.	1
WÜRTEMBERG, . .	. . . . .	1655 ; 1837 ; 1846 ; 1851 ; 1855 + 1 ; 1871 ; 1873 ; 1875 ; 1880.	10
WURTZBURG, . . .	. . . . .	841 ; 1138 + 19 ; 1872.	22
WYE RIVER, BASIN OF, .	. . . . .	1853.	1
WYNENTHAL, UPPER, .	Aargau Canton, . . .	1855.	1
WYNINGEN, . . .	Berne Canton, . . .	1817.	1
XANTHI, ...	Turkey, ...	1829, very violent, +40 (lasted for 40 days)—jets of water and large fish thrown up from fissures formed ; 1861 W.–E. ; 1863.	41
XICOCHORI, . . .	North of Negropont, . .	1859.	1
YAKA, ...	Anatolia, ...	1874, violent, not a house left standing.	1
YALOVA, ...	Anatolia, ...	1857.	1
YORK, ...	. . . . .	844 ; 1201 ; 1574 ; 1754 ; 1780 ; 1795 ; 1821.	7
YORKSHIRE, . . .	. . . . .	1704 ; 1738 ; 1817 ; 1863 + 1.	4
YORKSHIRE, WESTERN, .	. . . . .	1869.	1
YVERDUN, . . .	Vaud Canton, . . .	1523 ; 1557 + 3 ; 1601 ; 1607 ; 1648 + 3 ; 1674 ; 1680 + 3 ; 1692 ; 1816 ; 1817 ; 1846 + 1 E.–W. ; 1847 + 4 ; 1876 ; 1877.	28
YVETOT, ...	Seine Inférieure, . .	1835 ; 1845 E.–W.	2
YVONAND, . . .	Vaud Canton, . . .	1817.	1
YVORNE, ...	Vaud Canton, . . .	1867.	1
YVOIRE, ...	Savoie, ...	1852.	1
YVRIL = IVRINDI, .	Anatolia, ...	1875, great crevices formed giving issue to springs, not a house left standing, 450 lives lost—(*Fuchs*).	1
YUZGAT, ...	South of Senope, Turkey, .	(1871 + 1) N.W.–S.E. + 1.	3
ZABAYER ISLANDS, .	Lat. 15° 7′ N. Long. 42° 12′ E. Red Sea, .	1846.	1
ZABRICE, . . near	Klana, Illyria, . . .	1870 + 1.	2
ZAFFERANA, . . .	Etna, Sicily, . . .	1852 ; 1853 ; 1868 + 1 ; 1869 + 3 ; 1879 ; 1880 + 10.	20
ZAILGROTZ, . . .	Hungary, ...	1784 + 3.	4
ZAIHOLI, ...	Achaia, Greece, . . .	1859.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ZAININGEN, . . .	Würtemberg, . . .	1855 + 2.	3
ZALA, ...	Croatia, ...	1880.	1
ZALA Comitat, . .	Hungary, ...	1880.	1
ZAMORA, . . .	Route from Setif to Boujie, [Algeria,	1850.	1
ZAMORA, ...	Spain, ...	1853.	1
ZAMORA, Province, .	Spain, ...	1880 + 3.	4
ZANGLINSK, . . .	Caucasus, ...	(1868 + 2) N.W.–S.E. + 2.	5
ZANTE, ...	. . . . .	*1514*; 1636 + 5; 1664; 1673; *1710*; *1742*; *1752*; 1767; 1769; 1783; *1785*; 1787; *1791* + 3; 1804 + 1; 1820 S.E.–N.W. + 2 + 1; 1821; 1835; 1837 + 1; **1840** + 100; *1841* + 3; 1842; 1843 + 24 + 1 W.S.W.–E.N.E. + 1 W.–E. + 1 S.–N.; 1844 + 56 + 1 W.–E. + 1 S.W.–N.E.; 1845 + 19; 1846 + 39 + 2 S.–N.; 1847 + 24 + 2 N.–S. + 1 E.–W.; 1848 + 36; 1849 + 14; 1850 + 25; 1851 + 20; 1852 + 32; 1853 + 42; 1855 + 25; 1856 + 22 + 1 W.S.W.–E.N.E.; 1857 + 14; 1858 + 23; 1859 + 13; 1860 + 20; 1861 + 11; (1862 + 1) N.–S. + 13 S.–N. + 2 N.E.–S.W. + 3 E.–W. + 4 N.–S. + 1 S.W.–N.E. + 1 S.E.–N.W.; 1863 + 9 S.–N. + 1 W.–E. + 1 N.N.E.–S.S.W. + 1 E.–W. + 1 N.–S. + 2; 1864 S.–W. + 7 S.–N. + 1 S.E.–N. + 1 E.–W. + 1 N.–S.; 1865 + 8 S.–N. + 2 N.–S. + 1 E.–W. + 2 + 3 S.–N., extended simultaneously to the Sporades Island; 1866 + 18 + 1 E.–W.; 1867 + 65; 1873; 1874.	781
ZARA = ZADAR, . .	Dalmatia, ...	1828 + 1; 1836; 1837 S.W.–N.E.; 1843; 1844; 1845; 1846 + 1, very violent, + 1; 1850 + 2 + 1, very violent, + 1; 1851; 1852; 1855; 1856; 1857 N.W.–S.E. + 1; 1864; 1865; 1872 S.W.–N.E. + 1; 1873 N.–S.; (1881 + 1) S.–N.; 1882 S.–N.	29
ZARDAT, ...	Caucasus, ...	1861.	1
ZARDOLE, . . .	Bakou Gov., Caucasus, .	1861.	1
ZARSKAJA, . . .	Cossak Country, Russia, .	1870.	1
ZARSKI-KOLODZY, .	. . . . .	1868.	1
ZAUNHAUS, . . .	Erzegebirge, Saxony, . .	1877.	1
ZAXATAL, . . .	Caucasus, ...	1867 + 1.	2
ZEALAND, . . .	. . . . .	1530; 1580; 1687; 1843; 1869.	5
ZEGNA, ...	Croatia, ...	1843 S.W.–N.E.	1
ZEIZ, ...	Saxony, ...	1832.	1
ZELINA, . . . near	Agram, ...	1880 + 2.	3
ZELL, ...	Carinthia, ...	1862 + 1.	2
ZELL, ...	Lucerne, ...	1870 W.–E. + 1; 1878; 1879 + 1.	5
ZELL, ...	Coblentz C., Rhenish Prussia,	1869.	1
ZEL AM SEE, . . .	Saltzbourg, ...	1864 W.–E.	1
ZELTINGEN, . . .	Bernkastel, C., Rh. Prussia,	(1869 + 1) S.E.–N.W.	2
ZENDJAN, . . .	Northern Persia, . . .	1879.	1
ZENEGGEN, . . .	Valais, ...	1855; 1857 + 4.	6

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ZENGG = SEGNA, . .	Croatia, ...	1648; 1843 S.E.–N.W. + 5, great disturbance of magnets, + 1 N.E.–S.W. + 4; (1868 + 5) S.W.–N.E. + 2 + 3 S.E.–N.W.; 1869 + 11; 1870 + 3; 1873 + 5; 1878 + 20.	65
ZERAMO, ...	*See* Teramo.		
ZERMATTHAL, . .	Valais, ...	1855 + 2.	3
ZERNATTEN, . . .	Valais, ...	(Several shocks from 1840 to 1845) + 3; 1855 + 25; 1862; 1877 + 1; 1880 + 6; 1881.	40
ZERNITZ, . . .	Lower Engadine, . .	1866 S.–N.; 1868 N.E.–S.W.; 1882.	3
ZIERL, ...	Tyrol, ...	1856.	1
ZINNWALD, . . .	. . . . .	1756 + 1; 1877.	3
ZIRÉ, . . , near	Innspruck, ...	1856.	1
ZITTAU, ...	Saxony, ...	1856 + 1.	2
ZITZA, ...	Epirus, 5 leagues N.W. of Janina,	1857; 1860 + 5.	7
ZLVIZOW, . . .	Galicia, Austria, . . .	1875.	1
ZNAIM, ...	Moravia, ...	1858.	1
ZOCCA, ...	Bologna, ...	1864.	1
ZOFFINGEN, . . .	Aargau Canton, . .	1870; 1881.	2
ZOGONOI = TZOGONOI, .	Daghestan, ...	1868.	1
ZONS, ...	Neus C., Rh. Prussia, . .	1869.	1
ZOURNABAD (SOURNABAD),	Lat. 40° 50′, Long. 43° 54′ Caucasus, .	1860; 1861 E.–W. + 1; (1862 + 1) N.E.–S.W.; (1863 + 1) N.E.–S.W.; 1865 E.–W. + 1 + 1 S.W.–N.E.; 1867 S.E.–N.W. + 3; 1868 + 3 + 1 E.–W.; 1869; 1870 + 8.	29
ZRING, ...	Hungary, ...	1829.	1
ZUCKMANTL, . . .	Silesia, ...	1878.	1
ZUG, CANTON OF, . .	. . . . .	1755; 1877.	2
ZUG, ...	. . . . .	1861 E.–W.; 1862 + 2 S.E.–N.W.; 1880.	5
ZÜLPICH, . . near	Cologne, ...	1812, 2 leagues radius, + 1.	2
ZURICH CANTON, . .	. . . . .	1652; 1705; 1716; 1720; 1721; 1755; 1855.	7
ZURICH CANTON, NORTHERN PART OF, ...		1881.	1
ZURICH, ...	. . . . .	1534; 1557 + 3; 1560; 1573 + 4; 1574; 1578, violent; 1601, violent; 1602, violent, + 3; 1667 + 3; 1672; 1704 + 1; 1705; 1711; 1720 + 1; 1728 + 2; 1729; 1787; 1800; 1802; 1826; 1827; 1837 + 2; 1838; 1839; 1841; 1851 + 2; 1852 E.–W.; 1855 N.–S. + 5; 1856 + 2; 1861 + 1; 1874; 1877; 1880 + 2; 1881 + 5.	70
ZURICH LAKE, . .	. . . . .	1826; 1827.	2
ZUTS, ...	Engadine, ...	1881 + 1.	2
ZUVELJE, . . . near	Ottocatz, Croatia, . .	1853 S.–N.	1

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ZURNABAD (*see* Zournabad), ...			
ZUYGLIUS, . . near	Grenoble, ...	1761 + 2.	3
ZVECEVO, . . .	Sclavonia, ...	1870 S.W.–N.E.	1
ZWEIBRÜCKEN, . .	Bavaria, ...	1869; 1880.	2
ZWEISIMMEN, . .	Berne Canton, . . .	1816 + 1; 1846; 1881; 1882 + 1 S.W.–N.E.	6
ZWENIHOROD = Dzwenigorod,	Galicia, Austria, . .	1880.	1
ZWICKAU, . . .	Saxony, ...	1859; 1862 S.E.; (1881 + 1) S.E.–N.W.	4
ZWIEFALTEN, . .	Würtemberg, . . .	1830.	1
ZWISCHENWASSER, .	Carniola, ...	1863.	1
ZWOLLE, ...	Ober Yessel, Holland, . .	1829.	1
ZWONITZ, . . .	Saxon Voigtland, . . .	1862 S.E.–N.W.	1
ZYRIANOFF, . . near	Tomsk, ...	(1867 + 2) W.–E.	3

For a number of the additions and corrections made for Great Britain and Ireland, I am indebted to the valuable Report on the East Anglian Earthquake of 22nd April, 1884, by Professor Raph. Meldola, F. C. S., and Mr. William White, F.E.S., which appeared in 1885, while the present Catalogue was passing through the Press.

ADDED IN THE PRESS.

PLACES.	LOCALITIES.	YEARS.	Total Number of Shocks recorded.
ALTHORP,		1755.	1
BECKENHAM,		1750.	1
BEVERLY,		1704.	1
BOTTESFORD,	Leicestershire,	1792.	1
BRECON,		1863.	1
BRECKNOCKSHIRE,		204, a city swallowed up.	1
BURRINGHAM MOORS,		1755.	1
CANTERBURY,		483, 1380, 1692.	3
CHETWOOD,		1869.	1
CHELTENHAM,		1863.	1
CHESHUNT,		1750.	1
COCKERMOUTH,		1786.	1
COLCHESTER,		1692.	1
COTTESWOLD HILLS,		1863.	1
COXHALL,		1692.	1
DORRINGTON, near	Shrewsbury,	1838.	1
GALWAY,		1863.	1
GLASTONBURY,		1275, church thrown down.	1
GRANTHAM,		1750.	1
HANWOOD, near	Shrewsbury,	1838.	1
IRELAND,		*1734*, houses and churches destroyed.	1
KETTERING,	Leicestershire,	1792.	1
LONGDEN, near	Shrewsbury,	1838.	1
LUDDINGTON,		1755.	1
MANATON,	Dartmoor,	1752.	1
MARKET HARBOROUGH,		1863.	1
MEOLE, near	Shrewsbury,	1838.	1
MONMOUTH,		1863.	1
MORELON HAMPSTEAD,	Dartmoor,	1752.	1
NAVENBY,		1704.	1
NEWCASTLE,		1768 + 1.	2
NEWARK,		1792.	1
ORMSIDE,	Westmoreland,	*1790 + 2.*	3
PONTESBURY, near	Shrewsbury,	1838.	1
ROSS,		1863.	1
RUSHDON,		1755.	1
RUTLAND,		1750 ; 1792.	2

ADDITIONS AND CORRECTIONS.

*** The figures added represent years.

Page 498. AHUM, *read* AHUN.

,, ,, AIGUILLON, *for* Lot and Garonne, *read* Lot et Garonne.

,, 500. ABIER-LE-JEUNE, *read* ALBIER-LE-JENNE.

,, 504. ANGERS, *for* Maine and Loire, *read* Maine et Loire.

,, 506. ARENDAL, *for* Nedennes, *read* Nedenaes.

,, 507. ARZENGAN, *for* Paschelic *read* Paschalic.

,, 508. ASCOLI, *for* Calabria, Capitanata, *read* Capitanata.

,, ,, ASPREMONT, *for* Hauts, Saône, *read* Haute Saône.

,, 509. AUTUN, *for* Saône-and-Loire, *read* Saône et Loire.

,, 511. BALAQUER, Cataluñia, *read* BELAGUER, Cataluña.

,, 519. BIRMINGHAM, *add* 1795; 1863.

,, 523. BOULOGNE-SUR-MER, *add* 1750.

,, 525. BRISIGHELLA, *for* De Ravenna, *read* Di Ravenna.

,, ,, BUCCARI, *for* Crotia, *read* Croatia.

,, 527. BURTON-ON-TRENT, *add* 1863.

,, 531. CARLISLE, *add* 1786.

,, 532. CARTMILL, *read* CARTMEL, Lancashire.

,, 534. CATALUÑIA Province, *read* CATALUÑA Province.

,, ,, CAVENGO, Bulluno Ter., *read* CAVENAGO, Milan Ter.

,, 538. CHIOS ISLAND, *add* = Khio = Scio, *and add* 1767.

,, 541. CONGLETON, *add* 1863.

,, 543. CORNWALL, *add* 424.

,, ,, COS ISLAND *add* = Ko = Stanko = Istankoi, *and add* 1672; 1856; 1863 + 2.

,, 544. COVENTRY, *add* 1750; 1795.

,, 545. CUMBERLAND, *add* 261, 1000 people and houses swallowed up; 1014; 1651; 1755.

,, 547. DARTMOOR, *for* 1732, *read* 1752, and neighbourhood.

,, 548. DERBY, *add* 1750; *1795*; 1863.

,, ,, DERBYSHIRE, *add* 1750, southern part of.

,, ,, DIEPPE, *for* Seine Inferieur, *read* Seine inférieure.

,, 549. DONCASTER, *add* 1795.

,, 550. DORNEGG, *for* near Feitzitz, *read* DORNEG, near Feistritz.

,, ,, DROH, *for* near Briskra, *read* Biskra.

,, 551. DUDLEY, *add* 1863.

,, 552. EDINBURGH, *add* 1816.

Page 553. EINSIEDELN, *for* Schwitz Canton, *read* Schwytz Canton.

,, 554. ELY, *add* 1750.

,, ,, ENGLAND, *add* **1133**; 1247; 1380; **1480**.

,, 555. ,, West of, *add* 1248.

,, 556. EU, *for* Siene, Inferieure, *read* Seine inférieure.

,, ,, EUROPE, *add 1186*; 1246; **1692**.

,, 557. EXETER, *add* 1863.

,, 558. FERENTINO, *for* Frozinone, *read* Frosinone.

,, 561. FRANCE, *add* 1580.

,, ,, FRANCHE CÓMTE, *read* FRANCHE-COMTÉ.

,, 562. FÜRFKIRCHEN, *read* FÜNFKIRCHEN.

,, 563. GALLICIA, Austria, *read* GALICIA, Austria.

,, 564. GARDIKI, *for* Epiris, *read* Epirus.

,, 567. GIGON, *read* GIJON.

,, ,, GIORNICO, *for* Ticinio Canton, *read* Ticino Canton.

,, 568. GLASGOW, *add 677*; 1816.

,, ,, GLOUCESTER, *add* 1812; 1863.

,, ,, GODERVILLE, *for* Seine, Inferieure, *read* Seine inférieure.

,, ,, GOMBASSI, *for* Florenec, *read* Florence.

,, 570. GRAISWODEN, *read* GRAISIVAUDAN.

,, ,, GRANZOY, *for* Deux Lèvres, *read* Deux Sèvres.

,, ,, GRAVILLE, *for* Seine, Inferieure, *read* Seine inférieure.

,, 571. GRIGNONCOURT, *for* Vorges, *read* Vosges.

,, 573. GUERNSEY ISLAND, *add 1799*.

,, 576. HÂVRE, *add* 1750.

,, 577. HEREFORD, *add* 1750; 1863.

,, ,, HEREFORDSHIRE, *add* 1574.

,, 579. HOSCHLITZ, *for* near Kremsis, Moravia, *read* near Kromau, Moravia.

,, ,, HOULME, LE, *for* Seine, Inférieure, *read* Seine inférieure.

,, 580. HULL, *add* 1869.

,, 581. ILLIEZTHAL, *read* ILLIERZTHAL, *and add* 1841 N.-S.; 1881.

,, 582. INVERNESS, *add* 1816, and country for 100 miles round.

Page 582. IPSWICH, *add* 1692.

,, 588. KENT, *add 1596.*

,, ,, KESWICK, *add* 1786.

,, 591. KŒVORDEN, *for* Dreuthe Province, *read* Drenthe Province.

,, 598. LEICESTER, *add* 1795.

,, ,, LEICESTERSHIRE, 1792.

,, 600. LINCOLN, *add* 1704; 1750.

,, ,, LINCOLNSHIRE, *add* 1107 or 1114; 1704; 1750; 1755.

,, 602. LIVERPOOL, *add* 1865.

,, 609. MARYPORT, *add* 1786.

,, 616. MONTE JEGO, *for* near San Sepolero, *read* San Sepolcro.

,, 622. NEATH, *add* 1812.

,, 624. NEWPORT, Monmouthshire, *for* 1860, *read* 1863.

,, ,, NICOMEDIA, *for* Bythyniæ, *read* Bythinia.

,, 626. NORMANDY, *add* 1692.

,, ,, NORTHAMPTON, *add* 1795.

,, ,, NORTHAMPTONSHIRE, *add* 1755.

Page 626. NORWICH, *add* **1480**; 1692.

,, ,, NOTTINGHAM, *add* 1750; *1795.*

,, ,, NOTTINGHAMSHIRE, *add* 1792.

,, 629. OISANS, *for* Iserè, *read* Isère.

,, 632. OXFORD, *add* 1795.

,, 636. PETERBOROUGH, *add* 1750.

,, 637. PICARDY, *add* 1750.

,, 639. PITTEN, *for* near Neukirchin, *read* near Neukirchen.

,, ,, POLAGO TORRES, *for* Beluno Ter., *read* Belluno Ter.

,, 657. ST. SEVER, *for* Landds, *read* Landes.

,, ,, ST. WENDEL, *for* Shenish Prussia, *read* ST. WENDER, Rhenish Prussia.

,, 658. SALESBURY, *read* SALISBURY.

,, 659. SAN JUAN de los Avadesas, Cataluñia, *read* SAN JUAN de las Abadesas, Cataluña.

,, 660. STA. MAGIA, *for* Houth Com., *read* Honth Com.

,, 661. SANTIAGO di Compostell, *read* SANTIAGO de Compostela.

XXIII.—*On some Properties of certain Plane Curves.* By R. A. Roberts, M.A.

[Read, December 14, 1885.]

I propose to consider in this Paper a few properties of certain plane curves included in the equation

$$x^n + y^n + z^n = 0, \tag{1}$$

especially with reference to the situation of the points of contact of the tangents drawn from a point. It may be observed, that if we suppose z to be the line at infinity, and x, y to pass through the circular points, the equation (1) assumes the well-known form in polar co-ordinates,

$$r^n \cos n\theta = a^n. \tag{2}$$

Let us consider the cubic

$$x^3 + y^3 + z^3 = 0; \tag{3}$$

then the tangents from the points a, b, c to the curve have their points of contact on the conic

$$ax^2 + by^2 + cz^2 = 0. \tag{4}$$

Now from (3) and (4) we have, if we put

$$x = a\alpha, \quad y = b\beta, \quad z = c\gamma, \tag{5}$$

$$\theta a^3 = \beta^2\gamma^2(\beta - \gamma), \quad \theta b^3 = \gamma^2\alpha^2(\gamma - \alpha), \quad \theta c^3 = \alpha^2\beta^2(\alpha - \beta), \tag{6}$$

where θ is indeterminate. Hence, if a, b, c lie on the curve, or $a^3 + b^3 + c^3 = 0$, we get $\Sigma\beta^2\gamma^2(\beta - \gamma) = 0$, which, being divided by $\Delta \equiv (\alpha - \beta)(\beta - \gamma)(\gamma - \alpha)$, gives $\alpha\beta + \beta\gamma + \gamma\alpha = 0$, or

$$ayz + bzx + cxy = 0. \tag{7}$$

We see thus that

$$ax^2 + by^2 + cz^2 + 2\lambda(ayz + bzx + cxy) = 0 \qquad (8)$$

represents any conic passing through the points of contact of the tangents drawn from the point a, b, c on the curve. Taking the discriminant of the equation (8) for a pair of chords of contact of the tangents, we obtain $\lambda^3 = -\frac{1}{2}$, and then taking its envelope subject to the condition $a^3 + b^3 + c^3 = 0$, we have

$$(x^2 - yz\sqrt[3]{4})^{\frac{3}{2}} + (y^2 - zx\sqrt[3]{4})^{\frac{3}{2}} + (z^2 - xy\sqrt[3]{4})^{\frac{3}{2}} = 0, \qquad (9)$$

which being cleared of radicals ought to give the square of the Cayleyan of one of the cubics of which the given curve is the Hessian.

I may mention here some properties of tangents to the curve (3), or rather of its homographic transformation

$$r^3 \cos 3\theta = a^3, \qquad (10)$$

whose points of contact lie on a line. The polar conic of the line $\alpha x + \beta y + \gamma z = 0$ with regard to the curve (3) is

$$\alpha^2 yz + \beta^2 zx + \gamma^2 xy = 0, \qquad (11)$$

which, therefore, we see, circumscribes the triangle of reference, or, in the case of the curve (10) is a circle passing through the pole. Hence, since the polar conic of a line with respect to a cubic touches the tangents to the curve at the points where it is met by the line, it follows that if tangents be drawn to the curve (10) at three collinear points, then one of the circles touching these tangents passes through the pole.

When we are given three tangents of the cubic (10), such that their points of contact are collinear, it is evident that the curve ought to be completely determined: and, therefore, that its pole ought to be one or other of certain points connected with the triangle formed by these tangents. I shall show now that the pole of the curve must be one of the points where the "nine-points" circle of the triangle is touched by the four circles which touch the sides. Let A, B, C be the tangents to a cubic at the points where it is intersected by a line D, then the equation of the curve can be written in the form

$$ABC - D^2F = 0, \qquad (12)$$

where F is a line which is called the satellite of D. Hence, the polar conic of a point is in this case

$$A'BC + B'CA + C'AB - 2D'DF - F'D^2 = 0, \qquad (13)$$

from which we see that the polar conic of the point DF circumscribes the triangle ABC, that is, the vertices of the triangle ABC are situated on a certain polar conic. Now the polar conic of a point with respect to the curve (10) is an equilateral hyperbola of which the pole of the curve is the centre, and we know that the "nine-points" circle of a triangle inscribed in an equilateral hyperbola passes through the centre. Thus we see that the "nine-points" circle of the triangle ABC passes through the pole of the curve; and as we have shown already that one of the circles touching the sides passes through the same point, the result which we have stated above becomes evident.

We can show, otherwise, that the "nine-points" circle of the triangle passes through the pole of the curve as follows:—If a conic Σ, written in tangential co-ordinates λ, μ, ν, have ABC for a self-conjugate triangle, it is easy to see that the result of substituting differential symbols, namely, $\frac{d}{dx}, \frac{d}{dy}, \frac{d}{dz}$ for λ, μ, ν, respectively, in Σ, and operating on ABC vanishes, and similarly if a conic touch D at its intersection with F, the result of operating in the same manner on D^2F vanishes; but a single conic can evidently be described to satisfy both these conditions; and, therefore, we see that the triangle ABC is self-conjugate with regard to a certain conic which is such that, if we substitute differential symbols in its tangential equation, then the result of operating on the equation of the curve vanishes. Now for the cubic (3) it is evident that such a conic must be of the form

$$f\mu\nu + g\nu\lambda + h\lambda\mu = 0, \qquad (14)$$

or for the curve (10) must be a parabola having the pole for focus. Hence we see that the required result follows from the fact that the "nine-points" circle of a triangle, self-conjugate with regard to a parabola, passes through the focus. By taking a particular case of the preceding result, when we are given a point on the curve and the corresponding tangent, we can construct the tangential and the corresponding tangent. Let O be the pole,

and P the point on the curve, then if P' is the reflection of P with regard to O, the line bisecting OP' at right angles meets the tangent at P in Q the tangential of P, and the tangent at Q is the other tangent drawn from Q to the circle passing through O, and touching PQ at P.

We may notice here a property of a circle and the curve (10). The cubic being written in the form (3), the tangential equation of a conic passing through the points xz, yz is

$$\Sigma \equiv (l\lambda + m\mu + n\nu)^2 - \lambda\mu = 0, \tag{15}$$

and then the locus of the poles with regard to the cubic of the tangents to the conic breaks up into the factors

$$lx^2 + my^2 + nz^2 \pm xy = 0\,; \tag{16}$$

and from the mode of generation it is obvious that these two conics intersect the curve (3) at the points where its tangents touch Σ. Hence, transforming to rectangular Cartesian co-ordinates, we readily infer that if six tangents of the curve

$$x^3 - 3xy^2 - a^3 = 0 \tag{17}$$

are touched by the circle

$$(x - x')^2 + (y - y')^2 - r^2 = 0, \tag{18}$$

then the corresponding points of contact will lie on the conic

$$(r + x')\,x^2 + (r - x')\,y^2 - 2y'xy - a^3 = 0, \tag{19}$$

and the points of contact of the six remaining common tangents of (17) and (18) lie on the conic obtained by altering the sign of r in (19).

If we form the invariant equation of the circle (18), and the corresponding conic (19), we find

$$\begin{aligned} &r^2\lambda^3 - \{\,x'^3 - 3x'y'^2 - a^3 - r\,(x'^2 + y'^2) - 2r^3\,\}\,\lambda^2 \\ &+ \{\,(x'^2 + y'^2 - r^2)^2 + 2a^3 r\,\}\,\lambda - a^3\,(x'^2 + y'^2 - r^2) = 0. \end{aligned} \tag{20}$$

Now it is evident that if the circle touch the curve, the circle and conic will touch each other at the same point. Hence we obtain by the theory of conics the condition that the circle (18) should touch the curve by

equating to zero the discriminant of (20), and by supposing r to be a constant, we thus have the equation of the parallel curve to (10).

If we combine with the discriminant of (20) the discriminant of the same equation with the sign of r changed, we evidently obtain relations between x', y', r corresponding to a system of circles having double contact with the curve, and by putting then $r^2 = -z^2$, we have the equations of a twisted curve which is the focal curve of (10). Again, if we express that the circle (18) has double contact with the conic (19), we obtain

$$y'^3 - 3x'y'^2 = 0, \tag{21}$$

$$(\delta - 2r)(\delta + r)^2 = a^3, \tag{22}$$

where $\delta^2 = x'^2 + y'^2$. We thus have three distinct systems of circles having double contact with the curve, which is, however, evident from the fact that the three lines (21) are axes of symmetry. The relation (22) evidently connects the length of the normal with the distance of its foot from the pole.

If we express that the equation (20) has three equal roots, we obtain the two conditions that the circle (18) should osculate the curve.

I now proceed to consider some properties of the curve

$$x^{\frac{1}{3}} + y^{\frac{1}{3}} + z^{\frac{1}{3}} = 0, \tag{23}$$

which, as is well known, is a cubic of which x, y, z are inflexional tangents, and the point 1, 1, 1 a node. Now for this curve it is easy to see that the points of contact of the tangents from the point a, b, c lie on the curve

$$ax^{-\frac{1}{3}} + by^{-\frac{1}{3}} + cz^{-\frac{1}{3}} = 0. \tag{24}$$

Hence, from (23) and (24), and making the substitution (5), we may write

$$\theta a^{\frac{1}{3}} = \alpha^{\frac{1}{3}}(\beta - \gamma), \quad \theta b^{\frac{1}{3}} = \beta^{\frac{1}{3}}(\gamma - \alpha), \quad \theta c^{\frac{1}{3}} = \gamma^{\frac{1}{3}}(\alpha - \beta),$$

whence we obtain

$$\theta^3 a = \alpha^2(\beta - \gamma)^3, \quad \theta^3 b = \beta^2(\gamma - \alpha)^3, \quad \theta^3 c = \gamma^2(\alpha - \beta)^3. \tag{25}$$

From these equations we find

$$\left.\begin{aligned} \theta^3(a+b+c) &= (\alpha\beta+\beta\gamma+\gamma\alpha)\Delta, \\ \theta^3(x+y+z) &= 3\alpha\beta\gamma\Delta, \\ \theta^3(a^2yz+b^2zx+c^2xy) &= xyz(\alpha+\beta+\gamma)\Delta, \end{aligned}\right\} \qquad (26)$$

where $\Delta=(\alpha-\beta)(\beta-\gamma)(\gamma-\alpha)$. Hence, restoring the values of α, β, γ, we easily deduce

$$S\equiv(bcx+cay+abz)(x+y+z)-3(a^2yz+b^2zx+c^2xy)=0, \qquad (27)$$

which must evidently represent a conic passing through the points of contact of the tangents drawn from the point a, b, c to the curve; and as the equation (27) is satisfied by the co-ordinates a, b, c, S is the conic described through a, b, c and the points of contact of the tangents drawn from that point to the curve.

The tangent to S at the point a, b, c is

$$3abc(x+y+z)-(a+b+c)(bcx+cay+abz)=0; \qquad (28)$$

and this, it is easy to see, is the tangent at the point a, b, c to the cubic of the system

$$(x+y+z)^3-\lambda xyz=0 \qquad (29)$$

which pass through that point. Hence, from geometrical considerations, we readily infer that the anharmonic ratio of the tangents drawn to the curve from any point of a given cubic of the system (29) is constant.

If S' is the polar conic of a, b, c with respect to the cubic (23), namely,

$$(a+b+c)(x+y+z)^2-9(ayz+bzx+cxy)=0,$$

it is evident that $S+\lambda S'$ will represent any conic passing through the points of contact of the tangents drawn to the curve from a, b, c, and if λ be determined so that the discriminant vanishes, we have the equations of the chords of contact of the tangents. This discriminant of $S+\lambda S'$ is found to be divisible by the Hessian of the cubic, the quotient being

$$\lambda^3-6(a+b+c)\lambda^2+9(a+b+c)^2\lambda-108abc=0. \qquad (30)$$

By means of this result (30) we can find the locus of the intersection of the tangents at the extremities of a chord which passes through a fixed point. Forming the equation of the chords of intersection of S and S', and expressing that this equation is satisfied by the co-ordinates of the fixed point, we obtain the equation of the locus, which is found to be of the ninth degree, except when the point is on the curve, in which case the locus reduces to the third degree. From the conic (27) we can find the equation of the chord of contact of the two other tangents which can be drawn to the curve from any point of an inflexional tangent. Putting $c = 0$, and dividing out by z, we get

$$ab(x + y + z) - 3(a^2y + b^2x) = 0, \tag{31}$$

which, when $a : b$ varies, touches the fixed conic $(x + y + z)^2 - 36xy = 0$.

I now proceed to consider the curve

$$x^{-2} + y^{-2} + z^{-2} = 0, \tag{32}$$

which in the form (2) is evidently the curve commonly called the Lemniscate of Bernouilli. In this case it is easy to see that the points of contact of the tangents drawn from the point a, b, c to the curve lie on

$$ax^{-3} + by^{-3} + cz^{-3} = 0. \tag{33}$$

Hence, substituting for x, y, z as in (5), we get from (32) and (33)

$$\theta a^{-2} = \alpha^3(\beta - \gamma), \quad \theta b^{-2} = \beta^3(\gamma - \alpha), \quad \theta c^{-2} = \gamma^3(\alpha - \beta), \tag{34}$$

from which, again, we obtain

$$\left.\begin{aligned} \theta(a^{-2} + b^{-2} + c^{-2}) &= (\alpha + \beta + \gamma)\Delta, \\ \theta(xa^{-3} + yb^{-3} + zc^{-3}) &= (\alpha^2 + \beta^2 + \gamma^2 + \alpha\beta + \beta\gamma + \gamma\alpha)\Delta. \end{aligned}\right\} \tag{35}$$

Thus restoring the values of α, β, γ, we have from (35)

$$\begin{aligned} (a^{-2} + b^{-2} + c^{-2}) \{ x^2a^{-2} + y^2b^{-2} + z^2c^{-2} + xy(ab)^{-1} + yz(bc)^{-1} + (zx)(ca)^{-1} \} \\ - (xa^{-1} + yb^{-1} + zc^{-1})(xa^{-3} + yb^{-3} + zc^{-3}) = 0, \end{aligned} \tag{36}$$

or

$$(b^2 + c^2)x^2 + (c^2 + a^2)y^2 + (a^2 + b^2)z^2 + abxy + bcyz + cazx = 0. \tag{37}$$

We see then from (36) that the points of the contact of the four tangents drawn from the point a, b, c on the curve lie on the line

$$bcx + cay + abz = 0,$$

the other factor being the tangent at a, b, c. This result was, I believe, first arrived at by Dr. Casey (see his *Memoir on Bicircular Quartics*).

From (37) we see that the points of contact of the six tangents drawn from any point to the curve lie on a conic; and of this result I give an independent proof as follows:—If we form the contravariant σ of (32), namely, the envelope of a line divided equianharmonically by the curve, we find $\sigma = (\lambda^2 + \mu^2 + \nu^2)^2$. Now if we put $bz - cy$, $az - cx$, $ay - bx$, for λ, μ, ν respectively in σ, it is easy to see that the result must be proportional to the invariant S of the biquadratic in k obtained by substituting $x + ka$, $y + kb$, $z + kc$ for x, y, z in (32). By these means we obtain the identical equation

$$12(U'U - PV) + Q^2 \equiv \{(bz - cy)^2 + (az - cx)^2 + (ay - bx)^2\}^2, \qquad (38)$$

where
$$\left.\begin{aligned} U &\equiv x^2y^2 + y^2z^2 + z^2x^2, \quad U' \equiv a^2b^2 + b^2c^2 + c^2a^2, \\ V &\equiv ax(y^2 + z^2) + by(z^2 + x^2) + cz(x^2 + y^2), \\ P &\equiv ax(b^2 + c^2) + by(c^2 + a^2) + cz(a^2 + b^2), \\ Q &\equiv (b^2 + c^2)x^2 + (c^2 + a^2)y^2 + (a^2 + b^2)z^2 + 4bcyz + 4cazx + 4abxy. \end{aligned}\right\} \qquad (39)$$

Hence, since V is the polar cubic of abc, putting $U = V = 0$ in (38) for the points of contact of the tangents from abc, we get the conic (37), the factor $bcyz + cazx + abxy$ being rejected as irrelevant.

We find the discriminant of the conic (37) to be proportional to

$$(a^2 + b^2 + c^2)(a^2b^2 + b^2c^2 + c^2a^2).$$

Taking the case when

$$a^2 + b^2 + c^2 = 0, \qquad (40)$$

the conic breaks up into the factors

$$ax + \theta by + \theta^2 cz = 0, \quad ax + \theta^2 by + \theta cz = 0, \qquad (41)$$

where θ is a cube root of unity. These two lines are tangents to the conics

$x^2 + \theta^2 y^2 + \theta z^2 = 0$, $x^2 + \theta y^2 + \theta^2 z^2 = 0$, respectively, and intersect each other at the point a^{-1}, b^{-1}, c^{-1}, which point, we see from (40), lies on the curve. If we interpret these results with reference to the lemniscate whose polar equation is $r^2 = 2c^2 \cos 2\theta$, we find that if tangents be drawn to the curve from any point of the equilateral hyperbola $2r^2 \cos 2\theta = c^2$, their points of contact will be situated on two lines which intersect on the curve, and touch, respectively, the equilateral hyperbolæ

$$2r^2 \cos(2\theta \pm \tfrac{2}{3}\pi) = c^2. \qquad (42)$$

It may be observed that the angle between these two lines is $\frac{2}{3}\pi$; from which we see that the curve can be generated as the locus of the intersection of tangents to two equilateral hyperbolæ such as (42), which cut at an angle equal to $\frac{2}{3}\pi$. In fact, however, we can see otherwise that a lemniscate can be generated as the locus of the intersection of tangents to two concentric equilateral hyperbolæ which cut at an angle equal to double that between the axes of the hyperbolæ.

From the identity (38) we can easily deduce that the polar line of any point a, b, c meets the curve at its points of intersection with the conics

$$ayz + bzx + cxy = 0, \quad bcyz + cazx + abxy = 0. \qquad (43)$$

We thus obtain the locus of the poles of the tangents to the curve by expressing that the conics (43) touch the curve or intersect on it. In the former case we obtain the conic $x^2 + y^2 + z^2 = 0$, and the curve itself; and in the latter case the curve

$$(x^2 + y^2 + z^2)(x^2y^2 + y^2z^2 + z^2x^2) - 9x^2y^2z^2 = 0. \qquad (44)$$

From (43) we infer that the tangent at a point a, b, c of the curve meets it again at its points of intersection with the conic $ayz + bzx + cxy = 0$; or in the case of the lemniscate $(x^2 + y^2)^2 - 2c^2(x^2 - y^2) = 0$, the tangent at x', y' meets the curve again at points lying on the circle

$$x^2 + y^2 + 2x'x + 2y'y = 0. \qquad (45)$$

From this result we can easily deduce that the length of the intercept of the tangent on the curve is equal to $\frac{2r}{c^2}\sqrt{(c^4 - r^4)}$; also that the locus of the

middle point of the intercept is $r^2 = 2c^2 \cos\left(\frac{2\theta}{5}\right)$, and that if ϕ is the angle subtended by the intercept at the pole, $\cos\phi = \frac{r^2}{c^2}$.

By means of the preceding results we can easily show that, if a line $lx + my + nz$ meet the curve (32), the tangents at the four points meet the curve again in eight points lying on the conic

$$l^4x^2 + m^4y^2 + n^4z^2 - 2(l^2 + m^2 + n^2)(mnyz + nlzx + lmxy) + 8lmn(lyz + mzx + nxy) = 0. \quad (46)$$

If we seek the discriminant of this conic we find

$$l^2m^2n^2\{(l^2 + m^2 + n^2)^3 - 27l^2m^2n^2\},$$

which is $l^2m^2n^2$ multiplied by the tangential equation of the curve, as it evidently ought to be.

By means of the result (45) we can evidently construct the polar of a point P with respect to the lemniscate as follows:—Let a circle passing through O the node, whose centre is P', the reflection of P with regard to O, meet the curve in A, B, then AB is the polar of P. We can also deduce, by means of (37), that if AB meet the curve again in C, D, and the tangents from P to the equilateral hyperbola $2r^2\cos 2\theta = c^2$ meet the circle passing through O, C, D in Q, R, S, T, then the six points A, B, Q, R, S, T lie on the conic which passes through the points of contact of the six tangents which can be drawn to the curve from P. For the conic (37) can be written in either of the equivalent forms,

$$(bcx + cay + abz)P - U'(ayz + bzx + cxy) = 0,$$
$$(a^2 + b^2 + c^2)(x^2 + y^2 + z^2) - (ax + by + cz)^2 + 3(bcyz + cazx + abxy) = 0,$$

where P and U' have the same values as at (39).

I now proceed to consider a few properties of the sextic curve

$$x^{\frac{2}{3}} + y^{\frac{2}{3}} + z^{\frac{2}{3}} = 0. \quad (47)$$

This curve is the polar reciprocal of the curve we have been just considering, and therefore we might consider its properties as an addition to those of that curve.

The points of contact of the tangents from the point a, b, c to the curve evidently lie on

$$ax^{-\frac{1}{3}} + by^{-\frac{1}{3}} + cz^{-\frac{1}{3}} = 0. \tag{48}$$

Hence, with the substitution (5), we have from (47) and (48),

$$\theta a^2 = \alpha(\beta-\gamma)^3, \quad \theta b^2 = \beta(\gamma-\alpha)^3, \quad \theta c^2 = \gamma(\alpha-\beta)^3. \tag{49}$$

Hence we have

$$\theta(a^2+b^2+c^2) = (\alpha+\beta+\gamma)\Delta, \tag{50}$$

$$\theta(ax+by+cz) = (\alpha\beta+\beta\gamma+\gamma\alpha)\Delta, \tag{51}$$

$$\theta(x^2+y^2+z^2) = 3\alpha\beta\gamma\Delta, \tag{52}$$

where $(\alpha-\beta)(\beta-\gamma)(\gamma-\alpha) = \Delta$.

Thus from (50) and (51) we have

$$S \equiv abc(x^2+y^2+z^2) - a^3yz - b^3zx - c^3xy = 0. \tag{53}$$

Again, from the polar curve of a, b, c with regard to the result of clearing (47) of radicals, namely, $(x^2+y^2+z^2)^3 - 27x^2y^2z^2 = 0$, we have

$$(ax+by+cz)(x^2+y^2+z^2)^2 - 9xyz(ayz+bzx+cxy) = 0, \tag{54}$$

whence from (51) and (52) we deduce

$$S' \equiv (a^2+b^2+c^2)^2(x^2+y^2+z^2) - 3(bcx+cay+abz)^2 = 0. \tag{55}$$

We thus have two conics S and S' passing through the points of contact of the four tangents which may be drawn through a point to the curve. If we suppose (47) to be a cone, and the axes x, y, z mutually rectangular, we see from (55) that the lines of contact of the tangent planes which can be drawn through a given point are edges of a right circular cone.

If we calculate the discriminant of $2\lambda S + S'$, we find that it is divisible by the factors

$$(a^2+b^2+c^2), \quad (a^2+\theta b^2+\theta^2 c^2), \quad (a^2+\theta^2 b^2+\theta c^2), \tag{56}$$

where θ is a cube root of unity, the quotient being

$$2abc\lambda^3 - (a^2+b^2+c^2)^2\lambda^2 + (a^2+b^2+c^2)^3 = 0. \tag{57}$$

The results obtained from the consideration of the factors (56) will be found to be merely the reciprocals of some already obtained for the case of the curve (32). From the equation (57), however, by forming the equation of the chords of contact of the tangents, we can find the locus of the intersection of the tangents at the extremities of a chord which passes through a fixed point, which is thus found to be a curve of the fifteenth degree. In the case where the point is on the curve, the locus reduces to the ninth degree.

Proceeding now to consider the curve

$$x^{-3} + y^{-3} + z^{-3} = 0, \tag{58}$$

the points of contact of the tangents from a, b, c lie on

$$ax^{-4} + by^{-4} + cz^{-4} = 0; \tag{59}$$

whence, with the substitution (5), we deduce

$$\theta a^{-3} = \alpha^4(\beta - \gamma), \quad \theta b^{-3} = \beta^4(\gamma - \alpha), \quad \theta c^{-3} = \gamma^4(\alpha - \beta). \tag{60}$$

Hence we obtain

$$\left.\begin{aligned} \theta(a^{-3} + b^{-3} + c^{-3}) &= (\alpha^2 + \beta^2 + \gamma^2 + \alpha\beta + \beta\gamma + \gamma\alpha)\,\Delta, \\ \theta(xa^{-4} + yb^{-4} + zc^{-4}) &= \{(\alpha + \beta + \gamma)(\alpha^2 + \beta^2 + \gamma^2) + \alpha\beta\gamma\}\,\Delta. \end{aligned}\right\} \tag{61}$$

Now the curve is of the twelfth class; therefore we see from (61) that the points of contact of the twelve tangents which may be drawn through a point lie on the cubic

$$\begin{aligned} &(xa^{-4} + yb^{-4} + zc^{-4})(x^2a^{-2} + y^2b^{-2} + z^2c^{-2} + xy(ab)^{-1} + yz(bc)^{-1} + (zx)(ca)^{-1} \\ &-(a^{-3} + b^{-3} + c^{-3})\{(xa^{-1} + yb^{-1} + zc^{-1})(x^2a^{-2} + y^2b^{-2} + z^2c^{-2}) + xyz(abc)^{-1}\}, \end{aligned} \tag{62}$$

and that the points of contact of the ten tangents drawn from any point on the curve lie on the conic

$$b^2c^2x^2 + c^2a^2y^2 + a^2b^2z^2 + abc(ayz + bzx + cxy) = 0. \tag{63}$$

It may be observed that some of the preceding results can be extended to the surfaces whose equations are of the form

$$x^n + y^n + z^n + u^n = 0, \tag{64}$$

the points of contact of the inflexional tangents which can be drawn through a point to the surface being considered in this case.

As an example, we find that the points of contact of the inflexional tangents, which can be drawn from any point a, b, c, d of the surface to

$$x^{-2} + y^{-2} + z^{-2} + u^{-2} = 0,$$

lie on the plane whose equation is

$$\frac{x}{a} + \frac{y}{b} + \frac{z}{c} + \frac{u}{d} = 0; \tag{65}$$

and that for any point not on the surface the points of contact lie on the quadric

$$\begin{aligned}(b^2c^2 + c^2d^2 + d^2b^2)\,x^2 + (a^2c^2 + a^2d^2 + c^2d^2)\,y^2 + (a^2c^2 + c^2d^2 + d^2a^2)\,z^2 \\ + (a^2b^2 + b^2c^2 + c^2a^2)\,u^2 + cd\,(c^2 + d^2)\,xy + ad\,(a^2 + d^2)\,yz + bd\,(b^2 + d^2)\,zx \\ + bc\,(b^2 + c^2)\,xu + ac\,(a^2 + c^2)\,yu + ab\,(a^2 + b^2)\,zu = 0.\end{aligned}$$

As a further example, considering the surface

$$x^{\frac{3}{2}} + y^{\frac{3}{2}} + z^{\frac{3}{2}} + u^{\frac{3}{2}} = 0, \tag{66}$$

we see that the points of contact of the inflexional tangents drawn from the point a, b, c, d lie on the surfaces

$$ax^{\frac{1}{2}} + by^{\frac{1}{2}} + cz^{\frac{1}{2}} + du^{\frac{1}{2}} = 0, \tag{67}$$

$$a^2x^{-\frac{1}{2}} + b^2y^{-\frac{1}{2}} + c^2z^{-\frac{1}{2}} + d^2u^{-\frac{1}{2}} = 0; \tag{68}$$

whence, if a, b, c, d lie on (66), we readily obtain, by the method used above,

$$\left(\frac{x}{a}\right)^{\frac{1}{2}} + \left(\frac{y}{b}\right)^{\frac{1}{2}} + \left(\frac{z}{c}\right)^{\frac{1}{2}} + \left(\frac{u}{d}\right)^{\frac{1}{2}} = 0. \tag{69}$$

Hence, combining this equation (69) with (67), we find that the points of

contact of the inflexional tangents drawn from the point a, b, c, d, on the surface, lie on the four quadric cones—

$$\left.\begin{aligned}
(a^{\frac{3}{2}}-d^{\frac{3}{2}})\left(\frac{x}{a}\right)^{\frac{1}{2}}+(b^{\frac{3}{2}}-d^{\frac{3}{2}})\left(\frac{y}{b}\right)^{\frac{1}{2}}+(c^{\frac{3}{2}}-d^{\frac{3}{2}})\left(\frac{z}{c}\right)^{\frac{1}{2}}&=0,\\
(a^{\frac{3}{2}}-c^{\frac{3}{2}})\left(\frac{x}{a}\right)^{\frac{1}{2}}+(b^{\frac{3}{2}}-c^{\frac{3}{2}})\left(\frac{y}{b}\right)^{\frac{1}{2}}+(d^{\frac{3}{2}}-c^{\frac{3}{2}})\left(\frac{u}{d}\right)^{\frac{1}{2}}&=0,\\
(a^{\frac{3}{2}}-b^{\frac{3}{2}})\left(\frac{x}{a}\right)^{\frac{1}{2}}+(c^{\frac{3}{2}}-b^{\frac{3}{2}})\left(\frac{z}{c}\right)^{\frac{1}{2}}+(d^{\frac{3}{2}}-b^{\frac{3}{2}})\left(\frac{u}{d}\right)^{\frac{1}{2}}&=0,\\
(b^{\frac{3}{2}}-a^{\frac{3}{2}})\left(\frac{y}{b}\right)^{\frac{1}{2}}+(c^{\frac{3}{2}}-a^{\frac{3}{2}})\left(\frac{z}{c}\right)^{\frac{1}{2}}+(d^{\frac{3}{2}}-a^{\frac{3}{2}})\left(\frac{u}{d}\right)^{\frac{1}{2}}&=0.
\end{aligned}\right\} \qquad (70)$$

Since the surface (66) is the reciprocal of the cubic

$$x^3+y^3+z^3+u^3=0,$$

we see, by reciprocation, that the tangent planes to this cubic, at the three points of inflexion of the section by a tangent plane, are touched by four conics, each of which passes through three co-planar vertices of the tetrahedron of reference.

XXIV.—*Observations on Lion-breeding in the Gardens of the Royal Zoological Society of Ireland.*

By V. Ball, M.A., F.R.S., F.G.S., M.R.I.A., Director of the Science and Art Museum, Dublin, and Hon. Sec. of the Royal Zoological Society. (Plate XVIII., and Tables).

[Read May 10th, 1886.]

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TABLES.

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1.—Introduction.

Having been frequently asked questions regarding the breeding of the lions in the Gardens of the Royal Zoological Society of Ireland, and finding it inconvenient and unsatisfactory to be obliged to reply in general terms, I have been led to investigate the records on the subject which still exist; and although I was at first somewhat discouraged, owing to the scattered nature of the available information, I found, on persevering, that by constructing various tables, and by applying cross-checks, I was enabled to evolve a connected history which, if not absolutely correct, in reference to some few still doubtful points, is a very close approximation, indeed, to the truth, and, as regards the genealogical table, by means of which the descent of our now famous stock may be traced, absolutely correct.

From Mr. Snow, the Superintendent of the Gardens, I have received some valuable assistance. By inquiries made from the older keepers he has been enabled to furnish me with a few links of which no printed or written record existed, and many of the queries which were noted down by me, as they presented themselves, have been in this way answered, and the facts are now, for the first time, regularly incorporated in a connected narrative. The records collected as to the birth of thirty-four litters, including a total of 131 cubs, during a period of nearly thirty years, are sufficiently numerous to justify some generalizations which are believed to constitute distinctly new contributions to the natural history of the lion. So far as I am aware there has not been in any other collection of animals any comparable experience of lion-breeding. Lion cubs have been born in many public and private zoological collections; but if there has been, perchance, in any of the great menageries a systematic attempt, during an equally long period, to produce, by careful selection of stock, a notable breed of lions, I can only regret that I have been unable to hear of any record of such an attempt having been successful.

Starting, therefore, on the assumption that there is no such record, I propose to make this Paper as exhaustive of the subject as the means at my

disposal admit of. In order to do so, I have been obliged to devote a very large amount of time to the careful perusal and collation of the minutes, accounts, and other records of the Society's Proceedings since the date of its foundation in the year 1830. In all upwards of one hundred manuscript volumes, printed reports, and other papers, have had to be carefully read and analyzed.

This Paper consists primarily of several tables, and secondly of the observations which have arisen from a consideration of the facts which they contain, together with some other information which has not been incorporated in them.

2.—History of the Stock.

Before passing to these special observations it may be useful to give a brief history of the stock from whence this breed of lions has been descended, together with such other information as may be necessary by way of introduction, but fuller and more detailed accounts will be found in the tables and in the section which deals with the special biographies of the principal members of the breeding stock.

The regular breeding stock was started, in 1855, by the purchase of a pair of imported lions from Natal. The first litter was born in 1857. If this be taken as the starting-point, the total period may, for the purpose of striking averages, be divided into three terms: the first extending for ten years, from 1857 to 1866, both inclusive. During this period forty-six cubs were born, the number of litters being twelve: of these cubs six were born dead, or survived but a short time, one was kept in stock, one is not traceable, and the remainder, namely, thirty-eight, were sold.

The second term extends over twelve years—from 1867 to 1878. It includes one period of high mortality, and another (1874–1878) during which, though the blood was preserved, breeding was interrupted; these five years may therefore be excluded, and the term accordingly reduced to seven years. During it forty-six cubs also were born, of which eleven were either born dead or died shortly afterwards, eight died at various ages in

the Gardens, one was kept for stock, and the balance, or twenty-six, were sold.

The last term, also covering seven years, from 1879 to 1885, has been of the three the most successful. During it thirty-nine cubs, belonging to eleven litters, were born: of these four were dead at birth, or died shortly afterwards, four died at various ages, the history of two is unknown, seven, including the present male, "Paddy," were in stock at the end of the year, and the balance, namely, twenty-two cubs, were sold; and the average prices obtained were higher than in the previous periods.

3.—Special Biographies of the Stock Lions.

In Table No. III. the facts as to the periods during which the several lions bred in the Gardens, the number of litters, and the number of cubs born in each year are set forth, separated for the sake of clearness from the other details which accompany them in Table I. In Table IV. the months in which the cubs were born are given under the names of each of the parents. Besides these statistics, it may be interesting to give short biographical sketches of each of the principal lions which formed the stock.

Males.—I. "Natal." This lion, and the lioness "Natalie," were purchased in May, 1855, for the sum of £285. They were said to have been imported from Natal. The first litter from this pair, consisting of one cub, was not born till December, 1857; it was followed by a litter of four in September, 1858, and a litter of five in September, 1859, in all ten cubs. "Natalie" died while nursing the last litter; but the cubs survived, one of them being the famous lioness, "Old Girl," whose history is given below. In 1860 another lioness was obtained, which appears in the tables under the name "Anonyma." She had nineteen cubs in five litters between the years 1861 and 1864, and in 1865 she was sold.

Already, in 1862, "Natal" had been put to "Old Girl," who became the mother of thirteen cubs in three litters, the last, consisting of five (2nd and 3rd of April, 1864), being born within a day of "Anonyma's" last litter, also of five. About the time of their conception, in December, 1863,

"Natal" appears to have sickened, and he died on the 11th January, 1864. His exact age is not known, but probably it was about twelve years, of which eight were spent in the Gardens. His progeny by three different lionesses, during a breeding period of six and a-half years, amounted to forty-two.

On his death his body was bought by Dr. Haughton, whose *post mortem* report was that he had died of fever, accompanied by pneumonia. His skeleton is now in the Museum of Trinity College.

II. "Old Charley," son of "Natal" and "Anonyma," was one of a litter of five, born on the 3rd April, 1864. In 1866 he was put to his step-sister, "Old Girl," and their progeny between this date and 1873 amounted to forty-two cubs in ten litters. He was also the father of a litter of four cubs out of "Biddy," which were born on the 18th September, 1871. He was therefore the father of forty-six cubs, and died in April, 1874, at the age of exactly ten years. His body was also purchased by Dr. Haughton for dissection.

III. "Young Charley," son of "Old Charley" and "Old Girl," was one of a litter of three cubs, born on 23rd December, 1872. Various attempts to procure him a mate having failed, owing to the death of two lionesses, and the return to the dealers of others which on arrival proved unsuitable, it was not till January, 1879, that breeding was recommenced—a lioness called "Victoria" having been then presented to the Society by the Committee of the British Association Local Fund. This lioness had by him seven cubs in three litters, the last, consisting of one cub, being born on the 26th February, 1881. Another lioness, "Zenobia," which was purchased on the 12th June, 1879, had by him seventeen cubs in four litters, the last having been born on the 14th February, 1883. Out of a third lioness, "Queen," he had three cubs, which were born on the 7th February, 1884. In all he was the father of twenty-seven cubs. He died of pneumonia on the 5th November, 1884, being therefore nearly twelve years old. His skeleton is now in the Science and Art Museum.

IV. "Paddy," son of "Young Charley" and "Victoria," and great grandson of "Natal," was one of a litter of three, born on the 9th October, 1879, and is therefore at present rising seven years old. He is the

father of eight cubs out of "Queen," and of four out of "Minnie," all born in 1885.

Females.—The duration of the lives of the stock lionesses in the Gardens and the number of cubs they respectively produced are duly set forth in the tables. Although the 131 cubs were distributed among nine mothers, there were only seven lionesses which regularly belonged to the breeding stock, since "Nellie" was in cub when purchased in April, 1869, and died in the following month, having given birth to three cubs, of which only one, "Victor Patrick," survived, and was reared by hand on cow's milk. Another lioness, "Biddy" (born in the Gardens on the 13th August, 1868), had but one litter of cubs (September, 1871), and was sold to the Zoological Society of London, when in cub, the following year. It may be added that at least four other lionesses died or were otherwise disposed of without having bred—two, called "Kitty" and "Judy," having been sold, and two others having died: see Table VI. The names of the seven breeding lionesses were "Natalie," "Anonyma," "Old Girl" (or "Henrietta"), "Victoria," "Zenobia," "Queen," and "Minnie." The last two are still alive, and among them all the only one deserving of a special biography is "Old Girl," about whom much has already been published, her fame as a mother and the incidents connected with her death having secured for her a wide reputation.

"Old Girl," who at one time of her life was called "Henrietta," was born on the 8th September, 1859, being one of a litter of five. The parents were the original pair, "Natal" and "Natalie;" and though the latter died while nursing, the whole of the cubs survived, four of them having been sold when about twelve months old. When about two and a-half years old, "Old Girl" was mated with her father, and produced her first litter of three in July, 1862; litters of four and five followed in 1863 and 1864. Owing to the death of "Natal" an interval followed; but in 1866 she had by her step-brother, "Old Charley," who was then two and a-half years old, a litter of four in October; this was followed by others in quick succession up to and including October, 1870, during which period of exactly four years she had thirty-five cubs in seven litters, two of them being litters of six each, and the average being five. In 1871 she had no cubs;

in 1872 she had two litters of three each; in 1873 she had her last litter of two. In all she had fifty-five cubs during eleven years, in two of which, however, none were born. Of these cubs six were dead at birth or died soon afterwards—a very small proportion, since fifteen of the remaining seventy-six cubs by other mothers were still-born or died under similar circumstances. Of the other forty-nine cubs four died of dysentery, after rearing, and three died in the Gardens when upwards of twelve months old, and one was kept as a stock lion, "Young Charley;" thus forty-one were left to be disposed of, and they realized a sum of upwards of £1400: this includes an estimated value for two of them, as the price or exchange obtained for them is not now traceable; *vide* Table VII. These remarkable results were obtained in spite of, perhaps some may think in consequence of, the very close breeding above indicated. Indeed, if the breeding had been since carried on in reference to this experience, instead of on the general principle of introducing new blood, the record might have been higher than it is.

"Old Girl" died of bronchitis on the 7th October, 1875, at the age of sixteen years. Before her death she had become very feeble and diseased, and was much troubled by the rats, which obtained access to her cage at night. A small terrier was therefore placed with her as a companion, and he did good service in protecting the noble invalid from a repetition of the injuries and indignities put upon her previously by the mischievous rodents.

4.—The Number of Cubs in a Litter.

It is a generally recognized fact that the lion, in its natural condition, may have in one litter any number of cubs from one to six; that a lion or tiger can rear more than three or four cubs in the wild state may, however, well be doubted.

The 131 cubs, belonging to thirty-four litters, give very nearly an

average of four cubs to a litter. The actual litters, too, show that the number four is predominant:—

Of	one-cub	litters	there were	2
,,	two	,,	,, was	1
,,	three	,,	,, were	8
,,	four	,,	,, ,,	14
,,	five	,,	,, ,,	7
,,	six	,,	,, ,,	2
			Total,	34

Aristotle's theory,* which is repeated by Pliny,† that the lioness begins by having five cubs, and one less every year, until having produced one only, she ceases to bear, is not borne out by the facts recorded in the above section devoted to special biographies, and also in Table III. The lioness "Old Girl," beginning with a litter of three, had, at about the middle of her breeding term, several litters of five and six in rapid succession, and towards the close of her life the numbers fell to three, and finally to two. Of the two litters of one cub each, whelped by other lionesses, one was a first, and the other a last litter.

5.—Monthly Periods of Maximum Production.

The facts in Table IV. and the curves in Table V., by means of which the same facts are diagramatically represented, indicate very distinctly that the experience obtained in the Gardens justifies the belief that there are *two* periods in the year at which lions, in a state of semi-domestication, bring forth more cubs than at other periods. By a singular coincidence, exactly twenty-two cubs were born, both in April and September; hence we have forty-four, or one-third of the total number, 131, born in one-sixth part of the whole term. If to April and September May and October be added respectively the totals become thirty-seven and thirty-nine, in all seventy-six, leaving only fifty-five for the

* "Περι ζωων Ιστοριας," VI. 31. † "Nat. Hist.," VIII. 17.

remaining eight months of the year, or a monthly average of seven, as against nineteen—a sufficiently striking difference, and one for which an explanation may be found, perhaps, in the habits of the lion when in the wild condition.

Most works which describe the lion in its native state are very meagre in reference to its breeding: indeed, the absence of well-authenticated information on the subject is quite remarkable. Aristotle, however, states that the lions of Syria bring forth cubs but once in the year, namely, in the spring.

The tiger, according to Mr. (afterwards Sir) Walter Elliot, as quoted by Dr. Jerdon (who himself gives no further information on the point), does not breed at any particular season: this may be true in the more or less equable climate of Southern India, but is scarcely likely to be the case further north, where the seasons are more distinctly defined.

Sir Joseph Fayrer says,* "the tigress gives birth to from two to five, even six, cubs. Three is a frequent number, and her period of gestation is about fourteen or fifteen weeks." He does not add anything as to the time of year when the cubs are usually born; and, I regret to say, that I do not possess any accurate information on the subject.

The period of gestation in lions is fifteen weeks; and although when from four to five months old the cub can be safely separated, it would seem probable that in the wild state they cannot leave their dam and forage alone till they are a full year old. Indeed their education is said to be not even then complete; but that they are still learning to kill when from one to two years old, during which time they are specially destructive to small animals. Under these circumstances, it seems most improbable that lions have more than one litter in the year when they are at large. In the case of tigers, it is a matter of common observation that cubs of up to two years of age are sometimes found in company with their mothers.

I am inclined to think it probable that in each geographical region the lion must have a particular time of year for producing cubs, and

* "The Royal Tiger of Bengal." London: Churchill; 1875, p. 22.

that owing to differences of climate the time varies; thus, in a dry tropical climate the births perhaps take place in the autumn, after the great heat and droughts of summer are over, while in more temperate climates the moderate heat of the summer would be of advantage to the cubs, so they may be brought forth in April and May. Hence the two periods of maximum production under domestication may be connected with two periods, which, under different conditions respectively are those common to the animal in a state of nature. This, of course, in the absence of data as to the times of birth in the wild state is merely speculation; but it may be confirmed hereafter. Supposing it to be well founded, the fact of cubs being produced occasionally in all the other months of the year would simply mean that a departure from the normal condition had been produced, as in the cases of cats and dogs, under the protective conditions of the semi-domesticated life. Anthropologists believe that certain seasonal observances among savage races of men are traditional survivals of "swarming periods." Among the Sonthals, an aboriginal tribe in India, for instance, I found indications suggestive of something of the kind. Civilization has however, so far as is known, obliterated distinct traces of the tendency itself; but birth statistics among savages might perhaps show that with them it still exists to an appreciable extent. It is difficult to believe that either the lion or tiger, in the wild condition, can breed in every month of the year; if they can the above argument goes for nought, and the predominance at particular times remains unexplained.

It has been suggested to me by Prof. J. D. Cunningham to compare the curves of production (see Table V.), modified into curves of conception, with monthly temperature curves, and to approach the question from the point of view adopted by Mr. Haycraft in his Paper "On Some Physiological Results of Temperature Variations."*

Mr. Haycraft has analysed the statistics of births in Scotland, and argues that a connexion exists between the periods of conception and the temperature. A want of complete concurrence between his theory and his

* "Trans. Roy. Soc. of Edinburgh." 1878–9, vol. xxix., Pt. I., p. 119.

facts he explains by the reputed influence of the festivities of a certain season of the year on these phenomena in Scotland.

Applying this theory to the case of the lions, we should find that the conception period for the April-May births, being fifteen weeks earlier, extended from about the middle of December to about the end of January, while the conception period for the September-October births extends from early in June to the first half or so of July.*

The average mean monthly temperatures of Dublin for twenty years, 1865 to 1884,† are as follows:—

January, . .	41·4	July, . . .	60·7
February, . .	43·2	August, . .	59·9
March, . . .	43·5	September, . .	59·9
April, . . .	48·1	October, . .	56·0
May, . . .	52·1	November, . .	44·4
June, . . .	57·7	December, . .	41·3

In June there is a marked rise in temperature, and the July temperature is the highest in the year. This agrees very well with the second conception period above given; but what about the first? It corresponds to the times of lowest temperatures in the year; but we must not forget the condition of the lion's house at this season. It is the period of short days, when, though they enjoy no special festivities, their house is kept closed for a greater number of hours than at any other period in the year, and it is well heated artificially. So that it may be suggested that the first maximum conception period is due to artificial (fire), and the second to natural (sun) heat. Having presented the above alternatives, I pass, in connexion therewith, to a consideration of the

6.—Geographical Distribution of the Lion.

Although the lion is in most persons' minds connected with Africa, still it is by no means restricted in its present range to that quarter of the

* It is expected that both lionesses now in stock will have cubs next October.—*Note added July*, 1886.

† I am indebted to Dr. J. W. Moore for this Table of Temperatures.

globe; and if we include in an account of its distribution the limits to which it reached in historical times alone, we shall find that it was formerly not uncommon in Greece, and in Asia Minor, where civilization and the invention of firearms have caused its extirpation. It is not very many years since it was killed as far eastwards in the peninsula of India as east longitude 84° 35′, where, in the valley of the Sone, near its junction with the Ganges, one is recorded to have been shot in the year 1814. Still more recently it has been shot in the neighbourhood of Allahabad; thus distinctly overlapping the proper range of the tiger—as indeed it still does to a less extent in Western India, especially in Guzerat, Cutch, and Central India. Within historical times, then, its range may be said to have extended from the Cape of Good Hope to Greece and Palestine, and from Morocco to the frontiers of Lower Bengal.

In prehistoric times, as we now know, the Cave lion was the contemporary of man even in Great Britain, and in the opinion of some palæontologists the Cave lion (*Felis spelæa*) is not, except by size, specifically separable from the modern lion (*Felis leo*).

7.—Colours and Markings of the Cubs.

The cubs when born are distinctly spotted with dark brown on a ground colour, which is rather light brown than fulvous. There are no minute records of the changes which take place in these marks; but from about one to three months they are, perhaps, most distinctly defined; and though along the back the spots are somewhat quadrangular in shape, there is no indication of actual bars or bands, and therefore it would appear that there must be some mistake in the following description of lion cubs by Prof. Mivart in his work on "The Cat":—"The young are marked with little transverse dark bands on each side of the body, and with a longitudinal black mark along the middle of the back."

Carefully drawn portraits of "Queen's" cubs, born April, 1885, by Mr. Thomas of Cardiff, as engraved in *The Graphic* for July 3rd, 1886, are, by the courtesy of the Proprietors of that Journal, given on Plate XVIII.

Spots, more or less well defined, are to be seen sometimes on the lower parts of adults, especially on the females.

8.—Sexes of the Cubs.

After much careful checking and counter-checking, it has been ascertained that there are good grounds for asserting that the sexes of 130 out of the total of 131 cubs are known. In former published lists in the Reports of the Royal Zoological Society for 1867 and 1869, and in the "British Medical Journal" for February, 26, 1876, the sexes of the two litters of five each, born in April, 1864, were stated to be unknown. But these cubs are referred to in one of the Garden note-books, when they were about to be disposed of, as four males, and five females, one having died. They have accordingly been so enumerated in Table II.

From this Table it will be seen that out of the 130, seventy-four were males, and fifty-six females, the percentage ratio of which is approximately fifty-seven to forty-three, or a majority of nearly fourteen males in every hundred cubs.

It is scarcely conceivable that any modification of the relative numbers of the sexes from that which obtains in the wild state can have arisen under the conditions in which these lions were bred. If the function which is fulfilled in nature by a preponderance of males be the survival of the strongest and healthiest, then these protective conditions should tend rather to diminish the difference in the relative numbers, since opportunities for combats do not exist. However, on the other hand, it may perhaps be maintained that the careful selection of stock has only been doing artificially what Nature performs by her own methods, and that there has been probably no appreciable effect upon the strongly implanted tendency in lions, as in some other animals, to produce more males than females. As is shown below, the ordinary mortality of male cubs has exceeded that of female cubs by a much smaller number than the births. Whatever view be taken, the important fact has been arrived at, from a consideration of the statistics of these 130 lion cubs, namely, that in every hundred the males exceeded the females by fourteen. This, so far as it goes, is probably a distinctly new contribution to the natural history of the larger carnivora.

The relative mortality of the two sexes has been as 7 : 13 at birth and while rearing, and as 10 : 2 afterwards; the total being as 17 : 15, or, say, 53 : 47 per cent., from which it would appear that in every hundred 6 more male cubs died than females during the same period; so that even without the combats above spoken of, the juvenile males seem to be subject to greater risks than the females. I do not, however, attach much importance to this estimate, as the result may, to some extent, be due to chance; but the greater proportion of male births is an absolute fact which cannot be much influenced by the comparative smallness of the data, as compared with those available when similar questions regarding men have to be discussed.

9.—General Mortality of the Cubs.

At first sight it would appear from Table II. that thirty-three out of 131 cubs died, or about twenty-five per cent.; but as at least four of these lived for twelve months and upwards, the proportion of juvenile mortality may be reduced to twenty-two per cent. Among those which were dead at birth, or died shortly afterwards, namely, twenty-one, the following is as exact a record of the causes as the facts now available admit of:—

Dead at birth,	2	Weakness,	9
Failure of mother's milk,	7	Causes not known,	3

In only one recorded case, that of "Victor Patrick," son of "Nellie," was an attempt to rear by hand from the first successful. This lion was born in May, 1869. As an experiment he was castrated by Dr. Haughton on the 17th March, 1870, and lived about three years. At the time of his death he had a growing and fairly promising mane; and no particular improvement in appearance, such as occurs in cats, seemed to have resulted from the operation which he had undergone.

10.—Age to which Lions attain.

As will be seen in the section devoted to special biographies, no lion or lioness has lived longer in the Gardens than sixteen years: indeed, only

one—"Old Girl"—attained that age. Judging from the decrepitude observed in several cases, we should be justified in saying that a lion of eleven or twelve years old is nearly worn out, and has not much longer to live. It would appear, however, that lions do attain greater ages. According to an authority, apparently Jules Gerrard, quoted in "Cassell's Natural History," the duration of a lion's life averages thirty-five years, and Buffon believed the limit to be twenty to twenty-two years. The great lion, "Pompey," which died in the Tower in 1760, is reported to have been seventy years old, and another is said to have reached the age of sixty-three. But I have recently been informed that the person responsible for these statements was not to be relied on.

11.—Dimensions and Markings of the Adults.

The stage of domestication which our lions have reached does not admit of any very accurate measurements being made, at least while they are alive; but, so far as can be ascertained, the present lion, "Paddy," aged six years on the 9th of October, 1885, is three feet six inches at the shoulder. This, according to the most recent accounts, is the ordinary height of full-grown African lions.

The following points, as exhibited by "Paddy," show the characteristics of the breed with which those of the several wild races of lions, as described and figured in Elliot's work on the *Felidæ*, and other books which treat of the same subject, may be compared:—

General body colour, . . .	Fulvous, or Tawny.
Colour of mane, ...	,, tipped with black.
Tuft of tail, ...	Black.
Ears, ...	Fulvous in front, black behind.
Corners of mouth, ...	Same as body colour.

The keeper, Patrick Rice, has informed me that he has frequently seen the small pointed horny appendage at the ends of the tails of the lions

which have died; but it is a structure easily detached, and in the case of "Old Charley" could not be found when he died in November, 1884.

A similar structure is found on the tail of the tiger, and is well known to the Indian *Shikaris*. Upon it was founded, as I believe, and have explained in the Proceedings of this Academy,* one of the characteristics of the *Martikhora* of the Greeks, which for so many centuries has been regarded as a wholly mythical animal, half tiger and half scorpion.

12.—Manes of Lions.

A well nigh ineradicable mistake has got possession of the field in spite of overwhelming testimony to the contrary—it is to the effect that the lions of India are maneless. This belief appears to have originated in an account of the Guzerat lion, which was published by Major Smee in the "Transactions of the Zoological Society of London." Commenting on this supposed specific distinction between the Indian and African lion, Dr. Jerdon merely admits that "the African lion has generally a finer mane, as well as a median line of lengthened hairs along the abdomen, which is seldom present in the Asiatic lion, and, moreover, has a somewhat different physiognomy." Blyth attributes the defective manes of some Indian specimens to their having been torn off by the prickly jungle inhabited by the lions.

Several years ago specimens of African and Indian lions were to be seen side by side in the Calcutta Zoological Gardens, and the legitimate conclusion, from a comparison, appeared to be that the Indian lion belonged to a distinguishable race, having the above characteristics, but that these were only of equivalent value to those which are found to exist in many other species of wild animals, which include geographical racial varieties.

In a newspaper extract I find the following having reference to the arrival of a Kattywar lion in the Bombay Zoological Gardens, in the year 1880: "He has a mane—Kattywar lions are usually said to be maneless; but that is a fable—and he has a splendid head and large eyes."

* 2nd Series, Polite Literature and Antiquities, vol. ii., No. 6.

The matter has been fully investigated by many zoologists, whose opinions it is not necessary to quote here. It is evident that undue prominence has been given to the fact that so-called maneless lions have been met with in India; but it would appear that similar varieties have been also found elsewhere. They were described by Pliny, and many others since his time.

13.—On the possibility of Crossing Lions with other Feline Animals.

The necessarily attendant risks have hitherto prevented any attempt being made in these Gardens to cross the lion with the tiger or leopard; as to the possibility of the latter there may be grave doubts. So far as I know there has been no recently recorded case; but, according to Pliny, the belief in what was described as the unfaithfulness of the lioness to her natural spouse in favour of the panther was very commonly believed by the Ancients.

As regards the lion and tiger breeding together, however, there would appear to be some trustworthy evidence. Sir William Jardine has figured one of a litter of lion-tiger cubs, which were whelped in Atkins' collection, in the year 1827. The skin of the cub figured was preserved in the Edinburgh Museum. Another litter of these hybrids was whelped at Windsor; but in neither case did they reach maturity. According to one account, there is not much difficulty in promoting this union; the period of gestation appears to be identical in both animals, namely, fifteen weeks.

I have received a letter from Mr. J. G. Robertson, of Kilkenny, in which he describes having seen a lion, tigress, and their three cubs, in the year 1832; their proprietor, a showman, had no other animals with him during his tour, which included a visit to Kilkenny.

14.—Cause of the Success in Breeding.

Although it may not be possible to say, certainly, that the success in breeding in the Dublin Gardens is attributable to any one particular

cause, still there are certain circumstances, which have, no doubt, mutually conduced to that result:—First, the careful selection of stock; second, abundance of fresh food, consisting of meat *with bone* (in the year 1864 horse flesh was substituted for beef, and has been given ever since): the horses, before being killed, are passed by a veterinary surgeon as being free from disease; third, separation of the sexes in different cages, the permitted interviews being of short duration; fourth, in the opinion of some, the nature of the cages, which have boarded instead of tiled floors, exercises some influence, and, under this belief, the floors of the cages in the Regent's Park Gardens have recently been boarded; fifth, and perhaps most important, the lions have, since the first up to last year, been under the watchful care of Patrick Rice, a keeper who had made himself thoroughly acquainted with them during his long course of service of over forty years. Any disturbance in their health has been promptly met by an alteration of the ordinary diet to cows' livers, paunches containing undigested vegetable food, or goat or rabbit flesh (fresh killed), according to the nature of the ailment. In more serious cases, the late Secretary and present President of the Society, the Rev. Dr. Haughton, sometimes assisted by other medical members of the Council, has prescribed courses of medical treatment. Lime water is now given to the cubs to counteract any tendency to rickets.

In a recently published work on Natural History* the want of success in breeding lions in the Regents Park Gardens, where the cubs of unrelated parents, during a considerable number of years, were born with cleft pallets, has been compared with the success in breeding lions in travelling menageries, and the explanation offered is, that the more exciting life under the latter condition is conducive to the production of cubs. This view receives no support from our experience, as the Dublin lions have but little to excite them and lead quite uneventful lives, their meals never being taken in the presence of such audiences as frequent the Regent's Park Carnivora House at feeding-time.

* Cassell's: vol. ii., p. 27.

15.—Food and Cost of Keep.

The changes in the lions' rations, from beef to horse flesh, to which reference has already been made, has, besides other good results, produced a very material reduction in the cost of keep. Last year the estimated cost of the food of an adult lion was £15. In former years it has been £28, £45, and even £66.

Even the last amount, high as it is, is very much less than, according to one account,* men who live in regions inhabited by lions have sometimes to pay towards their support. Thus it is said that in Algeria, twenty years ago, a single lion would destroy cattle, horses, and camels to the value of £240 a-year. So that if the duration of a lion's life was, as is asserted, thirty-five years, his depredations would have cost £8400. I can conceive it to be quite possible that tigers in some parts of India kill cattle to the value of £1 to £2 a-week, but I find it difficult to believe that a destruction of cattle such as is indicated by the above calculation for the lion could continue without complete extermination of all the flocks and herds within reach.

To the cost of food, given above, interest on capital, rent, keepers' wages, &c., would have to be added to arrive at a full estimate of the expenditure involved in lion-breeding.

16.—Commercial Aspects of the Question.

The investigations which have been made in the course of the preparation of this history have necessarily resulted in the accumulation of a mass of details as to the disposal of the cubs. And though there is no desire to see any increase in the number of Zoological collections in which lion-breeding is commercially successful, still the temptation to describe the success of an undertaking of this nature is so great, and the not unnatural

* "Cassell's Natural History," Vol. II., p. 24.

curiosity which has been shown as to the details so general, that I have been led to conclude with an account which, while it discloses some secrets of the trade, does not precisely put every one who might desire it in a position wherein a steady income can be earned.

The total sum realized in twenty-six years, from 1859, when sales commenced, till the end of 1885, by the sale of eighty-five cubs, amounts, as will be seen, to £3117 10*s*., a large portion of which was paid by the receipt of other animals in exchange, many of them being the most important acquisitions ever made to the collections in the Gardens. During periods, which have not been unfrequent, when the purchasing power of the Society was limited by a contracted exchequer, the young lions afforded a means of keeping up the general stock of the collection. According to whether the term be dated from 1855, when the stock was first obtained, or from 1859, when sales began, the annual gross income to the Society from the sale of lions has been £100 or £120.

As a preliminary to the table of sales of cubs, the statement as to purchase and sales of stock is of some importance; from it the fact is apparent that some of the lionesses purchased proved useless, and their names do not therefore appear in the other tables, as they were never regularly incorporated in the breeding stock.

Although we possess records of purchases and sales of lions, which took place before 1855, they do not belong to the period under consideration, and are therefore omitted.

With but few exceptions, the sales were to regular dealers in animals, through whose hands the cubs have passed far and wide, till it may be said their reputation has reached the most distant countries where there are Zoological Gardens, and Dublin bred lions have been known to have been exhibited, as such, in several of the towns of the United States, in Peru, and in India.

Although the names of the well-known dealers with which individual transactions have taken place need not be given, it may be said that almost all the cubs have been sold to the following:—M'Cost, Hulse, Herring, Jamrach, Rice, Cross, Stevens, Bostock, and Hamlyn.

One lioness, born in the Gardens, was sold to the Regent's Park Gardens

in 1872, where she had cubs shortly afterwards, but whether they survived or not is not known.

It may be added that, so far as possible, every effort has been made to ensure that the new lionesses, when purchased, should be of well-authenticated fresh blood; but it is needless to say that the risk of having had one of the cubs returned again has been considerable, though if suspected there is no certain knowledge that it has actually ever happened.

TABLE II.—*Showing the* NUMBERS *and* SEXES *of* 131 LION CUBS, *belonging to Thirty*
between the years

YEAR.	MONTH AND DAY.	Serial Number.	MOTHER'S NAME.	Number in Litter.	Males.	Females.	unk
1857	November 17, ...	1	"Natalie,"	1	—	1	
1858	September 20, ...	2	,, ...	4	2	2	
1859	September 8, ...	3	,, ...	5	4	1	
1861	May 18, ...	4	"Anonyma," . . .	4	1	3	
1861	December 7, ...	5	,, ...	3	1	2	
1862	May 30, ...	6	,, ...	4	4	—	
1862	July 8, ...	7	"Old Girl," . . .	3	—	3	
1863	August 3, ...	8	,, ...	4	1	3	
1863	September 5, ...	9	"Anonyma," . . .	4	1	3	
1864	April 2, ...	10	"Old Girl," . . .	5	4	5	
1864	April 3, ...	11	"Anonyma," . . .	5			
1866	October 3, ...	12	"Old Girl," . . .	4	2	2	
1867	June 16, ...	13	,, ...	5	2	3	
1868	January 4, ...	14	,, ...	6	5	1	
1868	August 13, ...	15	,, ...	5	2	3	
1869	April 16 to 18, ...	16	,, ...	5	3	2	
1869	May 24, ...	17	"Nellie,"	3	1	2	
1870	February 12, ...	18	"Old Girl,"	6	4	2	
1870	October 9, ...	19	,, ...	4	4	—	
			Forward, . .	80	41	38	

tters which were born in the GARDENS OF THE ROYAL ZOOLOGICAL SOCIETY OF IRELAND,
nd 1885 *inclusive.*

Dead Birth or while earing.	Died after rearing.	Kept for Stock.	Available for Sale.	REMARKS.
—	—	—	1	Sale not recorded.
—	—	—	4	
—	—	1 ♀	4	The female cub which was kept was the famous "Old Girl," or "Henrietta."
—	—	—	4	
3	—	—	—	Premature birth, one dead; the others died on the following day.
—	—	—	4	
1 ♀	—	—	2	One died on the 1st of September; had been weakly from birth.
—	—	—	4	
1 ♀	—	—	3	One female born dead; it was eaten by its mother.
—	—	—	5	
(?)	—	1 ♂	3	One of unrecorded sex, died soon after birth, and one male kept afterwards, known as "Old Charley," died April 5, 1874.
—	—	—	4	
—	—	—	5	
2 ♂	—	—	4	Two males died within the first week after birth.
1 ♀	1 ♂	—	3	One female (?) died soon after birth. A male ("Paddy") and a female ("Biddy") were kept for some years; "Paddy" died April 3, 1873, and "Biddy" was sold to the London
1 ♀	—	—	4	Birth protracted over three days; one female died soon after. [Gardens, June 6th, 1872.
2 ♀	1 ♂	—	—	Two females, bottle-fed, but died, one on 29th June, the other 1st July. The male ("Victor Patrick") was reared by hand.
1 ♀	—	—	5	One female died on 27th February.
—	4	—	—	Two cubs died on the 13th February, and two others on the 19th February, 1871, aged upwards of four months, all of dysentery.
13	6	2	59	

TABLE II.—*Showing the* NU

YEAR.	MONTH AND DAY.	Serial Number.	MOTHER'S NAME.	Number in Litter.	Males.	Females.	ur
			Brought forward, .	80	41	38	
1871	September 18, ...	20	"Biddy,"	4	2	2	
1872	March 10, ...	21	"Old Girl,"	3	2	1	
1872	December 23, ...	22	,,	3	2	1	
1873	October 23, ...	23	,,	2	—	2	
1879	April 11, ...	24	"Victoria,"	3	2	1	
1879	October 9, ...	25	,,	3	2	1	
1879	November 8, ...	26	"Zenobia,"	4	4	—	
1880	September 13, ...	27	,, ...	5	3	2	
1881	February 26, ...	28	"Victoria,"	1	—	1	
1881	October 23, ...	29	"Zenobia,"	4	2	2	
1883	February 14, ...	30	,,	4	4	—	
1884	February 7, ...	31	"Queen,"	3	2	1	
1885	April 2, ...	32	,,	4	3	1	
1885	May 5, ...	33	"Minnie,"	4	3	1	
1885	November 5, ...	34	"Queen,"	4	2	2	
					74	56	
			TOTAL, . .	**131**		**131**	

nd SEXES, *&c.—continued.*

Dead Birth or while earing.	Died after rearing.	Kept for Stock.	Available for Sale.	REMARKS.
13	6	2	59	
4	—	—	—	All died before 22nd September, from failure of their mother's milk.
—	1 ♀	—	2	The female died on the 5th of May, 1873, at the age of 14 months (called "Biddy II.").
—	1 ♀	1 ♂	1	The female died on the 2nd of January, 1874, aged 12 months. The male kept, afterwards known as "Young Charley."
—	—	—	2	There is some doubt as to the sex of these, but the Minutes of April 4, 1874, speak of them as females.
3	—	—	—	
—	—	1 ♂	2	The male kept is the present Lion "Paddy."
—	—	—	4	
—	—	—	5	
1 ♀	—	—	—	A female born in February was taken from its mother and reared in Superintendent's House; died 7th April.
—	—	—	4	
—	4	—	—	These all died from rickets at various ages.
—	—	—	3	
—	—	—	4	The keeper thinks there were five, one of which was born dead: if so it was eaten by the mother.
—	—	—	4	Two sold during 1885, and two in stock at end of year (one sold since, April, 1886, and one died in June).
—	—	—	4	All in stock at end of 1885 (2 ♀ and 1 ♂ sold since, April, 1886, and one ♂ in stock).
21	12	4	94	
		131		

TABLE III.—*Showing the* OFFSPRING *of the* MALE *and* FEMA

PARENTS' NAMES AND DATES.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.
MALES.														
"Natal," 1857–1864, ...	1	4	5	—	4+3	4+3	4+4	5+5	—	—	—	—	—	—
"Old Charley," 1866–1874, . . .	—	—	—	—	—	—	—	—	—	4	5	6+5	5	6+4
"Young Charley, 1879–1884, . . .	—	—	—	—	—	—	—	—	—	—	—	—	—	—
"Paddy," 1883–1885, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	1	4	5	—	7	7	8	10	—	4	5	11	*5	10
FEMALES.														
"Natalie," 1857–1859, ...	1	4	5	—	—	—	—	—	—	—	—	—	—	—
"Anonyma," 1861–1864, ...	—	—	—	—	4+3	4	4	5	—	—	—	—	—	—
"Old Girl," 1862-1873, ...	—	—	—	—	—	3	4	5	—	4	5	6+5	5	6+4
"Nellie," 1869, ...	—	—	—	—	—	—	—	—	—	—	—	—	3	—
"Biddy," 1871, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—
"Victoria," 1879–1881, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—
"Zenobia," 1879–1883, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—
"Queen," 1884–1885, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—
"Minnie," 1885, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Totals. . .	1	4	5	—	7	7	8	10	—	4	5	11	8	10

Breeding STOCK *respectively, and the* YEARS *in which they were* BORN.

1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	Totals.	Number of litters.	PARENTS' NAMES.
																MALES.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	42	11	"Natal."
3 + 3	2	—	—	—	—	—	—	—	—	—	—	—	—	47	11	"Old Charley."
—	—	—	—	—	—	—	3 + 3 + 4	5	1+4	—	4	3	—	27	8	"Young Charley."
—	—	—	—	—	—	—	—	—	—	—	—	—	4 + 4 + 4	12	3	"Paddy."
6	2	—	—	—	—	—	10	5	5	—	4	3	12	128	33	
														*3	1	"Nellie's" cubs, born, 1869, but not bred, in Gardens.
														131	34	
																FEMALES.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	3	"Natalie."
—	—	—	—	—	—	—	—	—	—	—	—	—	—	20	5	"Anonyma."
3 + 3	2	—	—	—	—	—	—	—	—	—	—	—	—	55	13	"Old Girl."
—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	1	"Nellie."
—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	1	"Biddy."
—	—	—	—	—	—	—	3 + 3	—	1	—	—	—	—	7	3	"Victoria."
—	—	—	—	—	—	—	4	5	4	—	4	—	—	17	4	"Zenobia."
—	—	—	—	—	—	—	—	—	—	—	—	3	4 + 4	11	3	"Queen."
—	—	—	—	—	—	—	—	—	—	—	—	—	4	4	1	"Minnie."
6	2	—	—	—	—	—	10	5	5	—	4	3	12	131	34	

TABLE IV.—*Showing the* MONTHS *in which the* BIRTHS *of* 131 CUBS *took place.*

PARENT'S NAMES.	Breeding Period.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
MALES.														
"Natal," . . .	8 years.	—	—	—	10	8	—	3	4	13	—	1	3	42
"Old Charley," . .	7 years.	6	6	3	5	—	5	—	5	4	10	—	3	47
"Young Charley," .	5 years.	—	8	—	3	—	—	—	—	5	7	4	—	27
"Paddy," . . .	1 year.	—	—	—	4	4	—	—	—	—	—	4	—	12
		6	14	3	22	12	5	3	9	22	17	9	6	128
Not bred in Gardens, .		—	—	—	—	3	—	—	—	—	—	—	—	3
						15								131
FEMALES.														
"Natalie," . . .	3 years.	—	—	—	—	—	—	—	—	9	—	1	—	10
"Anonyma," . .	4 years.	—	—	—	5	8	—	—	—	4	—	—	3	20
"Old Girl," . . .	11 years.	6	6	3	10	—	5	3	9	—	10	—	3	55
"Nellie," . . .	1 year.	—	—	—	—	3	—	—	—	—	—	—	—	3
"Biddy," . . .	1 year.	—	—	—	—	—	—	—	—	4	—	—	—	4
"Victoria," . . .	3 years.	—	1	—	3	—	—	—	—	—	3	—	—	7
"Zenobia," . . .	5 years.	—	4	—	—	—	—	—	—	5	4	4	—	17
"Queen," . . .	2 years.	—	3	—	4	—	—	—	—	—	—	4	—	11
"Minnie," . . .	1 year.	—	—	—	—	4	—	—	—	—	—	—	—	4
		6	14	3	22	15	5	3	9	22	17	9	6	131

Table VI.—Purchases *and* Sales *of Stock* Lions.

Purchases.			£	s.	d.	Sales.			£	s.	d.
1855	May, .	Pair of Lions, "Natal" and "Natalie,"	285	0	0	1865	Oct. 1,	Lioness "Anonyma," . £50 0 0			
1860	. .	Lioness "Anonyma," exchange, say	80	0	0	1870	Feb. 24,	Lioness "Judy," . . 80 0 0			
1869	April 22,	Lioness "Nellie," in cub, exchange, say	80	0	0	1870	. .	Lioness "Kitty," . . 60 0 0			
,,	Oct. 16,	Two young Lionesses, "Kitty" and "Judy"; both were sold in 1870,	100	0	0	1883	Feb. 13,	Lioness "Victoria," . . 70 0 0			
									260	0	0
1877	Jan. 27,	Lioness, died soon afterwards,	90	0	0	1864 to 1885					
1877	Feb. 16,	Lioness, daughter of the Clifton Gardens Lion "Hannibal"; died soon afterwards,	70	0	0			Sales of dead Lions for anatomical purposes, say, ...	50	0	0
1879	Jan. .	Lioness "Victoria"; presented by the British Association Local Committee; sold in 1883,	100	0	0			Value of stock in hand:—			
								Lion, say, . £250 0 0			
								Two Lionesses, . 240 0 0			
1879	June 12,	Lioness "Zenobia"; died 19th Aug., 1884,	80	0	0			Six cubs, . . 225 0 0			
									715	0	0
1883	Feb. 2,	Two Lionesses, "Queen" and "Minnie." These are at present in the Gardens,	240	0	0						
		Note.—A Lion from Morocco, presented by Her Majesty the Queen in 1860, died shortly after arrival.						Balance, . . .	100	0	0
			£1125	0	0				£1125	0	0

TABLE VII.—DETAILS *as to the* DISPOSAL *of* NINETY-FOUR LION CUBS, *born in the* GARDENS *of*

Serial Number of Litter.	DATE OF BIRTH.	Cubs available for Sale.	Purchaser.	DATE OF SALE.
1	1857, November 17, . . .	1 ♀ . . .	—	—
2	1858, September 20, . . .	4 { 1 ♀ . . .	A . .	1859, March, . . .
		1 ♂ . . .	B . .	1859, June 2, . . .
		2, 1 ♂ and 1 ♀ .	B . .	1860, March 1, . .
3	1859, September 8, . . .	4 { 1 ♂ . . .	B . .	1860, August 4, . .
		1 ♂ . . .	B . .	1860, August 18, . .
		2 ♂ . . .	C . .	1860, October 20, . .
4	1861, May 18, . . .	4 { 3 ♀ . . .	B . .	1862, January 28, . .
		1 ♂ . . }	B . .	1863, May 23, . .
6	1862, May 30, . . .	4 { 3 ♂ . . }		
		1 ♂ . . .	B . .	1863, September 1, . .
7	1862, July 8, ...	2 ♀ . . .	D . .	1863, June 27, . . .
8	1863, August 3, . . .	4, 1 ♂ and 3 ♀ }	D . .	1864, January 14, . .
9	1863, September 5, . . .	3, 1 ♂ and 2 ♀ }		
10	1864, April 2, ...	5 { 1 ♂ . . .	E . .	1866, October, 20, . .
		1 }		
		3 } 7, 2 ♂, 5 ♀ .	E . .	1864, November 12, . .
11	1864, April 3, ...	3 }		
12	1866, October 3, . . .	4 { 2, ♂ and ♀ .	F . .	1867, April 4, . . .
		1, ♂ . . .	E . .	1867, June 15, . . .
		1, ♀ . . .	G . .	1868, January 16, . .
13	1867, June 16, . . .	5 { 2, 1 ♂ and 1 ♀ .	F . .	1867, November 28, . .
		2, 1 ♂ and 1 ♀ .	E . .	1868, January 4, . .
		1 ♀	F . .	1868, January 11, . .
14	1868, January 4, . . .	4, 3 ♂ and 1 ♀ .	E . .	1868, June 13, . . .
15	1868, August 13, . . .	3 { 2, 1 ♂ and 1 ♀ .	H . .	1869, April 22, . .
		1 ♀	I . .	1872, June 6, . . .
	Forward,	50		

OYAL ZOOLOGICAL SOCIETY OF IRELAND, *and available for* SALE *between the Years* 1857 *and* 1885.

Age.	Price. £	s.	d.	Remarks.
—		—		No precise record, though one account says this Lioness was sold in March, 1859, for £80.
6 months.	50	0	0	
8 ,,	30	0	0	
18 ,,	100	0	0	
12 ,,	35	0	0	In exchange.
12 ,,	40	0	0	In exchange.
13½ ,,	70	0	0	In exchange.
8 ,,	75	0	0	
24 ,,	100	0	0	These four Lions were sold together for £160. The proportions of the price are as given in the Stock Book, but they seem somewhat unequal.
12 ,,	60	0	0	
16 ,,	60	0	0	
11 ,,	50	0	0	
5½ ,,	175	0	0	
4½ ,,				
32 ,,	140	0	0	This Lion was called "Tom." Sold for £120 cash, and three Hog Deer valued at £20.
7 ,,	140	0	0	
6 ,,	80	0	0	
9 ,,	50	0	0	
5 ,,	50	0	0	
5 ,,	60	0	0	
6½ ,,	60	0	0	
7 ,,	12	10	0	This low price appears to have been in consequence of death, after delivery, of one sold previously to same dealer.
5 ,,	135	0	0	£120 in cash, and three Madagascar Lemurs valued at £15.
8½ ,,	80	0	0	Exchanged for the Lioness "Nellie," she being then in cub.
6 ,,	80	0	0	This Lioness was known as "Biddy." She had four cubs by "Old Charley" in September, 1871, and was in cub when sold to the Zoological Society of London.
Forward,	£1732	10	0	

Table VII.—Details *as to the* Disposal

Serial Number of Litter.	Date of Birth.	Cubs available for Sale.	Purchaser.	Date of Sale.
	Forward,	50		
16	1869, April 18, . . .	4 { 2 ♂ . . . ; 2, 1 ♂ and 1 ♀ . }	H. .	1869, October 16, . .
			. . .	. . . . .
18	1870, February 12, . . .	5, 4 ♂ and 1 ♀ .	E. .	1870, December 29, . .
21	1872, March 10, . , .	2 ♂ . . .	E. .	1872, August 15, . .
22	1872, December 23, . . .	1 ♂ . . .	E. .	1873, July 16, . . .
23	1873, October 23, . . .	2 ♀ . . .	E. .	1874, April 9, . . .
25	1879, October 9, . . .	2 { 1 ♀ . . . ; 1 ♂ . . }	F. .	1880, August 28, . .
			F. .	1880, October 6, . .
26	1879, November, 8, . . .	4 { 2 ♂ . . ; 2 ♂ . . . }	F. .	1881, April 1, . . .
27	1880, September 13, . .	5 { 2 ♀ . . . ; 3 ♂ . . . }	F. .	1881, April 4, . . .
			F. .	1881, September 8, . .
29	1881, October 23, . . .	4, 2 ♂ and 2 ♀ .	F. .	1882, March 11, . .
31	1884, February 7, . . .	3, 2 ♂ and 1 ♀ .	D. .	1884, November 28, . .
32	1885, April 2, ...	4, 3 ♂ and 1 ♀ .	J. .	1885, August 22, . .
33	1885, May 5, ...	2, 1 ♂ and 1 ♀ .	F. .	1885, December 5, . .
	Total, . . .	88		

STATEMENT:—	
Total sold, ...	8
Unrecorded, ...	
In stock, end of 1885, . . .	
Total, .	9

NINETY-FOUR LION CUBS, *&c.—continued.*

Age.	Price.			Remarks.
	£	*s.*	*d.*	
Forward,	1732	10	0	
6 months,	60	0	0	These four cubs were known as "Shem," "Ham," "Japheth," and "Judith"; they were exchanged for two Lionesses, "Kitty" and "Judy," and £60; but two were afterwards re-sold to Gardens for £100. There is no subsequent record of the sale of these two: perhaps they died.
. . .	.	.	.	
10 ,,	150	0	0	
5 ,,	65	0	0	
7 ,,	50	0	0	
5½ ,,	50	0	0	
11 ,,	50	0	0	Exchange for Male Bison.
11 ,, say,	135	0	0	Exchange for Bison Cow, £25 of birds, and £50 cash.
17 ,,	100	0	0	Exchange two Cubs and two Bears for Bison Cow and £65.
7 ,,	100	0	0	Exchanged for two Leucoryx Antelopes.
12 ,,	120	0	0	An exchange of these for a pair of Giraffes was cancelled, and £100 cash and twenty animals accepted instead.
4½ ,,	200	0	0	In part consideration for a pair of Elephants.
8½ ,,	100	0	0	
4½ ,,	125	0	0	An Ourang Outang received as part of price.
7 ,,	80	0	0	A Dromedary, &c., received as part of price.
Price, .	£3117	10	0	

Average Price, £36 13*s.* 6*d.*

One of litter No. 1, and two of litter No. 16.

Two of litter No. 33, and four of litter No. 34.

Available for sale as in Table II. of Births.

Table VIII.—Prices *obtained at* Different Ages.

Years.	5 months.		6 months.		7 months.		8 months.		9 months.		10 months.		11 months.		12 months.		12 to 15 months.		15 to 18 months.		18 months and over.	
	Cubs.	£	Cubs.	£	Cubs.	£	Cubs.	£	Cubs.	£	Cubs.	£	Cubs.	£	Cubs.	£	Cubs.	£	Cubs.	£	Cubs.	£
1859	–	—	1	50	–	—	1	30	–	—	–	—	–	—	–	—	–	—	–	—	–	—
1860	–	—	–	—	–	—	–	—	–	—	–	—	–	—	2	75	2	70	2	100	–	—
1862	–	—	–	—	–	—	3	75	–	—	–	—	–	—	–	—	–	—	–	—	–	—
1863	–	—	–	—	–	—	–	—	–	—	–	—	2	50	3	60	–	—	1	60	1	100
1864	7	175	–	—	7	140	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—
1866	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—	1	140
1867	2	60	2	80	–	—	–	—	1	50	–	—	–	—	–	—	1	50	–	—	–	—
1868	4	135	–	—	2	60	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—
1869	–	—	2	60	–	—	–	—	2	80	–	—	–	—	–	—	–	—	–	—	–	—
1870	–	—	–	—	–	—	–	—	–	—	5	150	–	—	–	—	–	—	–	—	–	—
1872	2	65	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—	1	80
1873	–	—	–	—	1	50	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—
1874	–	—	2	50	–	—	–	—	–	—	–	—	3	135	–	—	–	—	–	—	–	—
1880	–	—	–	—	–	—	–	—	–	—	–	—	1	50	–	—	–	—	–	—	–	—
1881	–	—	–	—	2	100	–	—	–	—	–	—	–	—	3	120	–	—	2	100	–	—
1882	4	200	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—
1884	–	—	–	—	–	—	–	—	3	100	–	—	–	—	–	—	–	—	–	—	–	—
1885	4	125	–	—	2	80	–	—	–	—	–	—	–	—	–	—	–	—	–	—	–	—
	23	760	7	240	14	430	4	105	6	230	5	150	6	235	8	255	3	120	5	260	3	320

Analysis of the Preceding Table—(VIII.).

Age.	Number sold.	Price.	Average.	Remarks.
		£ s. d.	£ s. d.	
5 months. . .	23	760 0 0	33 0 0	
6 ,, . . .	7	240 0 0	34 0 0	
7 ,, . . .	14	430 0 0	30 14 3	£31 0s. 0d. for Cubs from five to eight months old.
8 ,, . . .	4	105 0 0	26 5 0	
9 ,, . . .	6	230 0 0	38 6 8	
10 ,, . . .	5	150 0 0	30 0 0	
11 ,, . . .	6	235 0 0	39 3 4	£34 18s. 3d., say £35, for Cubs from nine to twelve months.
12 ,, . . .	8	255 0 0	31 15 0	
12–15 ,, . . .	3	120 0 0	40 0 0	£40 0s. 0d. for Cubs from twelve to fifteen months.
15–18 ,, . . .	5	260 0 0	52 0 0	£52 0s. 0d. for Cubs from fifteen to eighteen months.
18 ,, and over,	3	320 0 0	106 13 4	£106 13s. 4d. for Cubs from eighteen months upwards.
	84	3105 0 0	. . .	£36 19s. 3d. for Cubs of all ages.
One sold under exceptional circumstances.	1	12 10 0	. . .	
	85	3117 10 0	. . .	£36 13s. 6d. for Cubs of all ages, reduced by one exceptional sale.

Note added in the Press.

It should perhaps be stated, in reference to Plate xviii. representing the cubs, that, while the outlines of the markings are accurately represented, the woodcut somewhat too sharply contrasts their colouration with that of the general unspotted portions of the pelage. Mr. Thomas's work is so faithful and spirited, that its insertion will, doubtless, be regarded as adding an attractive and important feature to this Paper.

Regarding the remarks made on page 735, as to the proportions of births of the two sexes in various animals, the following extract from the "Manual of Public Health for Ireland" may be read with interest:—

"It has long been observed that more boys than girls are born into the world. Quetelet has compiled a Table, based on observations collected by Captain Bedras (whose numerical units are seventy millions in number), showing the proportion of boys to girls born in the different countries of Europe. In Russia there are 108·9 boys to 100·0 girls, and in Great Britain 104·7: the mean for Europe is 106 boys to 100 girls. The Registrar-General of England says:—'The birth-registers of England have established the fact that more boys than girls are born, the proportion over a series of years being, in round numbers, 104 boys to 100 girls. Sometimes, but only twice within the last twenty years, the ratio becomes 105 to 100; while on two occasions (1871 and 1868) it has fallen below 104 to 100.'"

The figures given for the lions, namely, 57 males out of a hundred, yield, when stated in the above ratios, 133 males, q. p., to 100 females.

I find I have omitted to state that the first list of cubs published in the Society's Report for 1867 was by Dr. A. W. Foote, to whom therefore the credit is due of having first drawn attention to the subject-matter of this Paper.

"QUEEN'S" CUBS, BORN APRIL, 1885.

TABLE I. GENEALOGICAL TABLE SHOWING THE PARENTAGE AND DATES OF BIRTHS OF 131 LION CUBS BORN BETWEEN 1857 AND 1885, INCLUSIVE.

	SERIAL NUMBER OF LITTERS	JANUARY.	FEBRUARY.	MARCH.	APRIL.	MAY.	JUNE.	JULY.	AUGUST.	SEPTEMBER.	OCTOBER.	NOVEMBER.	DECEMBER.	NUMBER OF CUBS IN EACH YEAR	
1855															1855
1856															1856
1857	1											1		1	1857
1858	2									30 4				4	1858
1859	3									8 5				5	1859
1860														0	1860
1861	4 & 5					18 4							7 3	7	1861
1862	6 & 7					30 4		8 3						7	1862
1863	8 & 9					Died in Japan			8 4	5 4				8	1863
1864	10 & 11				28 5 5									10	1864
1865														0	1865
1866	12										7 4			4	1866
1867	13	6					16 5							5	1867
1868	14 & 15	4							13 5					11	1868
1869	16 & 17		6		16 18 5	24 3								8	1869
1870	18 & 19		12		OLD CHARLEY	VICTOR PATRICK					9 4			10	1870
1871	20			3						18 4				4	1871
1872	21 & 22			10		Died							23 3	6	1872
1873	23										33 2			2	1873
1874					Died 5th April									0	1874
1875														0	1875
1876														0	1876
1877														0	1877
1878														0	1878
1879	24,25 & 26				11 3						9 3	10 4		10	1879
1880	27									13 5				5	1880
1881	28 & 29		26 1								33 4			5	1881
1882														0	1882
1883	30		14 4											4	1883
1884	31		7 3		5 4	5 4							Died 3 Nov	3	1884
1885	32,33 & 34										In Stock 5 4			12	1885
	Totals	6	14	3	22	15	5	3	9	22	17	9	6	131	

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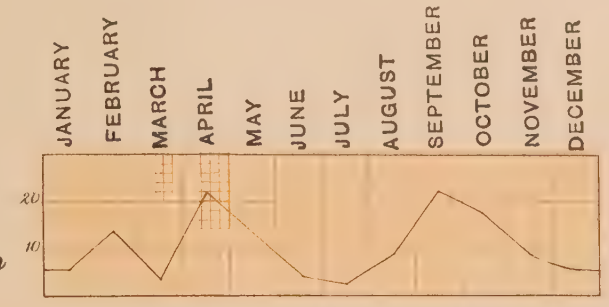
EXPLANATION.—The red and blue lines represent the periods during which the Stock Lions and Lionesses respectively, lived in the Gardens.

The red dotted lines connect the parents, and show the years when they were first put together.

The blue dotted lines connect the mothers with the litters, the number of the cubs in each litter being represented by the numerals placed in the spaces which indicate the year, month, and day of birth.

Where one of the red or blue lines originates near a numeral it is to be understood that the Lion or Lioness represented by that line was one of the litter to which the numeral refers.

TABLE V. CURVES SHEWING THE RELATIVE PROPORTIONS OF BIRTHS IN EACH MONTH IN THE YEAR.



Total number of Cubs born in the Gardens from 1857 to 1885. — *131 Cubs in 34 Litters*

MALES

Natal's Cubs, 1857 to 1864 — *42 Cubs in 11 Litters*

Old Charley's Cubs, 1866 to 1873 — *47 Cubs in 11 Litters*

Young Charley's Cubs, 1879 to 1884 — *27 Cubs in 8 Litters*

Paddy's Cubs, 1885 — *12 Cubs in 3 Litters*

FEMALES

Anonyma's Cubs, 1861 to 1864 — *20 Cubs in 5 Litters*

Old Girl's Cubs, 1862 to 1873 — *55 Cubs in 13 Litters*

Zenobia's Cubs, 1879 to 1883 — *17 Cubs in 4 Litters*

NOTE.—The ordinates give the number of births, and the abcissæ the months of the year in which the births have taken place.

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THE

TRANSACTIONS

OF THE

ROYAL IRISH ACADEMY.

VOLUME XXVIII.

SCIENCE.

XXV.—*Geometrical Theorems.* By JOHN C. MALET, M.A., Professor of Mathematics, Queen's College, Cork.

DUBLIN:
PUBLISHED BY THE ACADEMY,
AT THE ACADEMY HOUSE, 19, DAWSON-STREET.
SOLD ALSO BY
HODGES, FIGGIS, & CO., GRAFTON-STREET.
AND BY WILLIAMS & NORGATE,
LONDON:
14, Henrietta-street, Covent Garden.
EDINBURGH:
20, South Frederick-street.
1886.

XXV.—*Geometrical Theorems.*

By John C. Malet, M.A., F.R.S., Professor of Mathematics, Queen's College, Cork.

[Read, January 25, 1886.]

In the following Paper I repeat some known work to preserve the connexion.

Section I.—*Plane Curves.*

1. "If with respect to a point O a system of right lines, coplanar with the point, be reciprocated, then the polar line of the point O, with respect to the system, will be reciprocated into a point which is the centre of mean position of the points which are the reciprocals of the system of right lines; and conversely, if a system of points in a plane be reciprocated, with respect to another point O in the same plane, then the centre of mean position of the points will be reciprocated into a right line, which is the polar line of the point O with respect to the system of right lines reciprocal to the given system of points.

Proof.—Take the point O as origin, and the equations of the lines

$$A_1 x + B_1 y + C_1 = 0,\ A_2 x + B_2 y + C_2 = 0,\ \&c.;$$

then the equation of the polar line of the origin, with respect to this system, is easily found to be

$$x\Sigma\frac{A_1}{C_1} + y\Sigma\frac{B_1}{C_1} + n = 0,$$

n being the number of lines.

Now, if $(x_1 y_1)$, $(x_2 y_2)$, &c., be the co-ordinates of the points which are the reciprocals, with respect to the origin of the right lines, we find

$$x_1 = -\frac{k^2 A_1}{C_1},\ y_1 = -\frac{k^2 B_1}{C_1};\ x_2 = -\frac{k^2 A_2}{C_2},\ y_2 = -\frac{k^2 B_2}{C_2};\ \&c.$$

where k is the radius of reciprocation.

Again, the co-ordinates of the reciprocal of the polar line being $\bar{x}$, $\bar{y}$, we have

$$n\bar{x} = -\Sigma\frac{A_1}{C_1},\quad n\bar{y} = -\Sigma\frac{B_1}{C_1}.$$

Hence

$$n\bar{x} = \Sigma x_1,\qquad n\bar{y} = \Sigma y_1,$$

and the theorem is proved.

2. Consider now Mac Laurin's theorem (see Salmon's *Higher Plane Curves*, 3rd Edition, Art. 136).

"If through a point O any two right lines be drawn meeting a given plane curve of the order n, in systems of points $P_1, P_2, \ldots P_n$, and $Q_1, Q_2, \ldots Q_n$, then the polar line of the point O, with respect to the curve, is the same as the polar line of O with respect to the system of chords $(P_1 Q_1)$, $(P_2 Q_2)$," &c.

Or letting the lines through O coincide—

"If through a point O any right line be drawn meeting a given plane curve of the order n in the points $P_1, P_2 \ldots P_n$, then the polar line of the point O, with respect to the curve, is the same as the polar line of the point, with respect to the tangents to the curve at the points $P_1, P_2 \ldots P_n$."

Hence, by reciprocation, with respect to the point O, we have the following theorems:—

"If to a curve of the class n any two systems of parallel tangents be drawn $(\sigma_1, \sigma_2, \ldots \sigma_n)$, and $(\tau_1, \tau_2, \ldots \tau_n)$, then the centre of mean position of the points of intersection of the pairs of tangents $(\sigma_1 \tau_1)$, $(\sigma_2 \tau_2)$, $\ldots$ $(\sigma_n \tau_n)$ is a fixed point."

Or more particularly, we have Chasles' theorem (Salmon, Art. 137)—

"If to a plane curve of the class n any system of n parallel tangents be drawn, the centre of mean position of their points of contact is a fixed point."

3. If now, in Mac Laurin's theorem, the point O is situated on the curve, the theorem may be modified as follows:—

If through the point O we draw a variable right line meeting the curve in the $n-1$ points, distinct from O, $(P_1, P_2, \ldots P_{n-1})$, then the locus of a point P, taken on the line so that $\frac{n-1}{OP} = \Sigma \frac{1}{OP_1}$, is the polar conic of O. Hence, as before, by taking two positions of the line through O, and then letting them coincide, we have the theorem—

"If through a point O, situated on a plane curve of the order n, a variable right line be drawn meeting the curve in $n-1$ points, distinct from O, the polar line of O, with respect to the tangents to the curve at these points, envelops a conic which touches the curve at the point O, viz., the polar conic of the point."

Hence, by reciprocation, we have the following modification of Chasles' theorem when the curve touches the line at infinity:—

"If to a plane curve of the class n, which touches the line at infinity, any system of $n-1$ parallel tangents be drawn, the locus of the centre of mean position of their points of contact is, in general, a parabola."

4. If, however, the point O, in Mac Laurin's theorem, be a point of inflexion, and we draw through it a line to meet the curve in $n-1$ points, distinct from O, $(P_1, P_2, \ldots P_{n-1})$, then the locus of a point P, taken on the line so that $\frac{n-1}{OP} = \Sigma \frac{1}{OP_1}$ is a right line, and, as before, we have the theorem—

"If through a point of inflexion O, of a plane curve of order n, any line be drawn to meet the curve in $n-1$ points distinct from O, then the polar line of O, with respect to the tangents to the curve at these points, is a fixed line."

By reciprocation we have—

"If to a plane curve of class n, which has the line at infinity for a cuspidal tangent, any system of $n-1$ parallel tangent lines be drawn, the centre of mean position of their points of contact is a fixed point."

5. Suppose now that a point O is a double point on a plane curve of order n; if through the point we draw any line to meet the curve in $n-2$ points distinct from O, $(P_1, P_2, \ldots P_{n-2})$, and on the line take a point P, so that $\frac{n-2}{OP} = \Sigma \frac{1}{OP_1}$, then the locus of the point P is the polar cubic of O, with respect to the curve. Hence, as before—

"If through a double point O, situated on a plane curve of order n, any right line be drawn to meet the curve in $n-2$ points distinct from O, then the polar line of the point O, with respect to the tangents to the curve at these $n-2$ points, envelops a cubic curve having O for a double point, viz., the polar cubic of the point O."

Hence, by reciprocation, we get the following modification of Chasles' theorem:—

"If to a plane curve of class n, which has the line at infinity for a double tangent, any system of $n-2$ parallel tangents be drawn, the locus of the centre of mean position of their points of contact is, in general, a curve of the third class, which also has the line at infinity for a double tangent line."

6. More generally we prove, in the same manner—

"If through a point O, which is a multiple point of order p on a plane curve of order n, we draw any right line to meet the curve in $n-p$ points distinct from O, then the polar line of the point O, with respect to the tangents to the curve at these $n-p$ points, envelops a curve of order $p+1$, which has the point O as a multiple point of order p."

And by reciprocation—

"If to a plane curve of class n, which is touched p times by the line at infinity, any system of $n-p$ parallel tangents be drawn, the locus of the centre of mean position of their points of contact is, in general, a curve of class $p+1$, which is also touched p times by the line at infinity."

7. Consider now Newton's theorem (Salmon's *Higher Plane Curves*, Art. 127)—

"If a variable right line moves preserving a fixed direction, then the locus of the centre of mean position of the n points, in which the line intersects a given plane curve of order n, is a right line."

Reciprocating, we have—

"If through any point P, on a fixed right line (AB), n tangents be drawn to a given curve of class n, then the polar line of A, with respect to these tangents, passes through a fixed point Q."

Now the polar line of any point O, on the line (AB), with respect to the system of tangents through P, is the same as the polar line of A with respect to the same lines; a theorem which is evident geometrically, or may be proved analytically, as follows:—

Take A for origin, and let the equation of (AB) be $y - kx = 0$; let the co-ordinates of O and P be respectively (α, β) and (α_1, β_1); then the equations of the tangent lines through P are of the forms

$$A_1(x-\alpha_1) + B_1(y-\beta_1) = 0, \quad A_2(x-\alpha_1) + B_2(y-\beta_1) = 0, \text{ \&c.};$$

then the equation of the polar line of A, with respect to this system of lines, is

$$\Sigma \frac{A_1(x-\alpha_1) + B_1(y-\beta_1)}{A_1\alpha_1 + B_1\beta_1} = 0;$$

which, since $\beta_1 = k\alpha_1$, becomes

$$\Sigma \frac{A_1(x-\alpha_1) + B_1(y-\beta_1)}{A_1 + B_1 k} = 0;$$

and the equation of the polar line of O, with respect to the same system of lines, is

$$\Sigma \frac{A_1(x-\alpha_1) + B_1(y-\beta_1)}{A_1(\alpha_1-\alpha) + B_1(\beta_1-\beta)} = 0;$$

which, since $\beta_1 = k\alpha_1$ and $\beta = k\alpha$, also becomes

$$\Sigma \frac{A_1(x-\alpha_1) + B_1(y-\beta_1)}{A_1 + B_1 k} = 0.$$

Hence the theorem is proved.

The reciprocal of Newton's theorem may therefore be stated more generally, as follows:—

"If through any point P, on a fixed right line (AB), n tangents be drawn to a given curve of class n, then the polar line of any other point O, on the line (AB), with respect to the system of tangents through P, passes through a fixed point Q."

Now in Newton's theorem, by taking two positions of the variable line, and then letting them coincide, it is seen that the diameter of the curve, corresponding to a given direction, is the same as the diameter of any system of tangents to the curve at the points where any position of the variable line intersects it.

Hence, in the reciprocal theorem, if $a_1, a_2, \ldots a_n$ be the points of contact of tangents to the curve from any point R in the line (AB), then the polar line of A (or any other point in the line (AB)), with respect to the lines

$$(Pa_1), \quad (Pa_2), \ \ldots \ (Pa_n),$$

also passes through the fixed point Q.

8. Let the co-ordinates of the points a_1, a_2, &c., be (x_1, y_1), (x_2, y_2), &c.; then, as before, taking (α_1, β_1) for the co-ordinates of P, the equation of the line (Pa_1) is

$$\begin{vmatrix} x, & y, & 1 \\ x_1, & y_1, & 1 \\ \alpha_1, & \beta_1, & 1 \end{vmatrix} = 0,$$

with similar equations for the lines (Pa_2), (Pa_3), &c.

Hence the equation of the polar line of A with respect to this system of lines is

$$\Sigma \frac{x(y_1 - \beta_1) - y(x_1 - \alpha_1)}{x_1\beta_1 - y_1\alpha_1} + n = 0;$$

which, since $\beta_1 = k\alpha_1$, may be written

$$\frac{1}{\alpha_1}\left\{x\Sigma\frac{y_1}{kx_1 - y_1} - y\Sigma\frac{x_1}{kx_1 - y_1}\right\} + (y - kx)\Sigma\frac{1}{kx_1 - y_1} + n = 0;$$

hence the polar line, as P varies, always passes through the fixed intersection of the lines

$$x\Sigma\frac{y_1}{kx_1-y_1}-y\Sigma\frac{x_1}{kx_1-y_1}=0,$$

and

$$(y-kx)\,\Sigma\frac{1}{kx_1-y_1}+n=0.$$

Solving these equations, we find for the co-ordinates of the point Q,

$$x=\frac{\Sigma\dfrac{x_1}{y_1-kx_1}}{\Sigma\dfrac{1}{y_1-kx_1}},\quad y=\frac{\Sigma\dfrac{y_1}{y_1-kx_1}}{\Sigma\dfrac{1}{y_1-kx_1}}.$$

These values of x and y must remain constant, as the point R, from which tangents to the curve are drawn, moves along the fixed line (AB); hence, observing that $\dfrac{1}{y_1-kx_1}$ is inversely proportional to the perpendicular from (x_1, y_1) to the line $y-kx=0$, we have the following theorem:—

"If from any point on a fixed right line (AB) n tangents be drawn to a given plane curve of class n, then the centre of mean position of the points of contact of these tangents, for a system of multiples proportional to the reciprocals of the perpendiculars from these points on the line (AB), is a fixed point."

If the right line be situated at infinity, the perpendiculars are equal, and the tangents parallel, and we get Chasles' theorem as a particular case of the above.

9. From the values of the co-ordinates of Q we have

$$\frac{n\sqrt{1+k^2}}{y-kx}=\Sigma\frac{\sqrt{1+k^2}}{y_1-kx_1}.$$

Hence,

"If from any point on a fixed right line n tangents be drawn to a plane curve of class n, the sum of the reciprocals of the perpendiculars from the points of contact of these tangents on the fixed line is constant."

Again, by reciprocation, we have the following theorem :—

"If through a fixed point A any right line be drawn to meet a given plane curve of order n in points $P_1, P_2, \ldots P_n$; then, if $p_1, p_2, \ldots p_n$ be the perpendiculars from A to the tangents to the curve at the points P_1, P_2, &c., and if π_1, π_2, &c., be the perpendiculars from another fixed point B on the same tangents taken in the same order; then $\Sigma\frac{\pi_1}{p_1}$ is constant."

Reciprocating again from an arbitrary point, we get—

"If from any point on a fixed right line (a) n tangents be drawn to a given plane curve of class n, and if $p_1, p_2, \ldots p_n$ be the perpendiculars from the points of contact of these tangents on the line (a), and if $\pi_1, \pi_2, \ldots \pi_n$ be the perpendiculars from the same points, taken in the same order, on another fixed right line (b), then $\Sigma\frac{\pi_1}{p_1}$ is constant."

If in the foregoing theorem the line (b) be supposed at infinity, we have as a particular case the theorem given at the beginning of this Article; and if (a) be supposed at infinity, we get again Chasles' theorem.

10. To return to the consideration of Newton's theorem.

Let the equation of the curve be written

$$ax^n + x^{n-1}(b + cy) + x^{n-2}(d + ey + fy^2) + \&c. = 0.$$

Then, if the variable right line move parallel to the axis of x, we get for the equation of the corresponding diameter,

$$nax + cy + b = 0.$$

Suppose now the direction of the axis of x determines on the curve a point at infinity, a vanishes, and the equation of the diameter becomes, as it should, $x = \infty$.

If in this case we seek the locus of the centre of mean position of the $n - 1$ finite points, where any line parallel to the axis of x meets the curve, we find

$$(n-1)cxy + fy^2 + (n-1)bx + ey + d = 0:$$

the equation of a conic on which also the axis of x determines a point at infinity.

As before, by taking two positions of the variable line, and then letting them coincide, we can prove that the diametral line of any system of $n-1$ tangents to the curve, at the finite points where any position of the variable line meets it, is always a tangent to this conic, the point of contact being the centre of mean position of the points of contact of the tangents.

By reciprocation we find—

"If from any point on a fixed tangent (AB) to a plane curve of class n, a system of $n-1$ tangents, distinct from (AB), be drawn to the curve, then the polar line of any point on (AB), with respect to this system of tangents, envelops a conic which also touches (AB).

For convenience I shall call this conic C.

Let, as before, P and R be two points on (AB), and let the points of contact of the $n-1$ tangents from R to the curve be $a_1, a_2, \ldots a_{n-1}$, and the co-ordinates of these points $(x_1, y_1), (x_2, y_2), \ldots (x_{n-1}, y_{n-1})$; then, if P vary, while R remains fixed, the polar line of any point on (AB), with respect to the system of lines $(Pa_1), (Pa_2), \ldots (Pa_{n-1})$, passes through a fixed point Q on the conic C, of which the co-ordinates are, as before, given by the equations

$$x = \frac{\Sigma \dfrac{x_1}{y_1 - kx_1}}{\Sigma \dfrac{1}{y_1 - kx_1}}, \quad y = \frac{\Sigma \dfrac{y_1}{y_1 - kx_1}}{\Sigma \dfrac{1}{y_1 - kx_1}};$$

the equation of the line (AB) being $y - kx = 0$.

These values of x and y do not, as before, remain constant as R varies; but satisfy an equation of the second degree, since in this case Q moves on the conic C.

It is to be observed that the tangent to the conic C at the point Q is the line (RQ).

In the case we are considering the theorems of Article 8, &c., are to be modified as follows:—

"If from any point on a fixed tangent (AB) to a given plane curve of

class n, $n-1$ other tangents be drawn to the curve, the locus of the centre of mean position of the points of contact of these tangents, for a system of multiples proportional to the reciprocals of the perpendiculars from these points on (AB), is a conic to which also (AB) is a tangent."

By supposing the line (AB) at infinity, we get as a particular case a theorem given before (Art. 3).

The theorem may also be stated as follows:—

"If we denote by $p_1, p_2, \ldots p_{n-1}$, the perpendiculars on (AB) from the points of contact of $n-1$ tangents to the curve from any point R on (AB), and by p the perpendicular on the same line from the point of contact of a tangent through R to the conic C; then $\frac{n-1}{p} = \Sigma \frac{1}{p_1}$."

By reciprocation we find—

"If through a fixed point A, situated on a plane curve of order n, any line be drawn to meet the curve in $n-1$ other points $P_1, P_2, \ldots P_{n-1}$, and if $p_1, p_2, \ldots p_{n-1}$ be the perpendiculars from A to the tangents to the curve at these points, and if $\pi_1, \pi_2, \ldots \pi_{n-1}$ be the perpendiculars to these tangents, taken in the same order, from another fixed point B, which is not on the curve; then the polar line of B with respect to these tangents, for a system of multiples proportional to $\frac{\pi_1}{p_1}, \frac{\pi_2}{p_2}$, &c., envelops a conic which passes through A."

If in this theorem the line through A intersects the conic in another point P, and if p and π be the perpendiculars from A and B respectively to the tangent to the conic at P, then we have $(n-1)\frac{\pi}{p} = \Sigma \frac{\pi_1}{p_1}$.

11. For the case of the line (AB) being a multiple tangent to the curve we easily get the following theorems:—

"If from any point R on a right line (AB), which is a multiple tangent of order m to a plane curve of class n, a system of $n-m$ tangents be drawn to the curve, and if p_1, p_2, &c., be the perpendiculars from their points of contact to (AB); then the locus of the centre of mean position of these points, for a

system of multiples proportional to $\frac{1}{p_1}$, $\frac{1}{p_2}$, &c., is a curve of class $m+1$, to which also the line (AB) is a multiple tangent of order m."

Again, if p be the perpendicular to (AB) from the point of contact of the tangent to this locus, through R, then $\frac{n-m}{p} = \Sigma \frac{1}{p_1}$.

More generally, take another fixed right line, and let π_1, π_2, &c., be the perpendiculars to it from the points of contact of the tangents to the first curve, and let π be the perpendicular to it from the point of contact of the tangent to the other curve; then $(n-m)\frac{\pi}{p} = \Sigma \frac{\pi_1}{p_1}$.

By reciprocation we get—

"If through a point A, which is a multiple point of order m on a plane curve of order n, any line be drawn to meet the curve in $n-m$ other points, and if p_1, p_2, &c., be the perpendiculars from A to the tangents to the curve at these points, and if π_1, π_2, &c., be the perpendiculars from another fixed point B to the same tangents, taken in the same order; then the polar line of B with respect to the system of tangents, for a system of multiples proportional to $\frac{\pi_1}{p_1}$, $\frac{\pi_2}{p_2}$, &c., envelops a curve of order $m+1$, which also has A for a multiple point of order m."

Again, if p and π be the perpendiculars from A and B respectively to a tangent to the latter curve at the point distinct from A, where the line through A intersects it, then $(n-m)\frac{\pi}{p} = \Sigma \frac{\pi_1}{p_1}$.

12. A particular case of Newton's theorem seems worth noticing. Referring to the equation of the curve as given in Art. 10, we see that if the direction of the axis of x determines on it a point of inflexion at infinity, we must have the conditions

$$a = 0, \text{ and } b + cy \text{ a factor of } d + ey + fy^2.$$

In this case the locus of the centre of mean position of the $n-1$ finite points, where any parallel to the axis of x meets the curve, reduces to a

line, and the locus is the same for the curve and for any system of $n-1$ tangents to the curve at the points where it is intersected by any position of the variable line.

Hence, as before, we infer the following theorems:—

"If from any point on a line (AB), which is a cuspidal tangent to a plane curve of class n, $n-1$ tangents, distinct from (AB), be drawn to the curve, and if p_1, p_2, &c., be the perpendiculars to (AB) from the points of contact of these tangents, then $\Sigma \frac{1}{p_1}$ is constant, and the centre of mean position of the points of contact, for a system of multiples proportional to the reciprocals of the perpendiculars, is a fixed point."

More generally, "if π_1, π_2, &c., be the perpendiculars from the same points, taken in the same order to another fixed line, then $\Sigma \frac{\pi_1}{p_1}$ is constant."

Hence, reciprocally—

"If through a point A, which is a point of inflexion on a plane curve of order n, any line be drawn to meet the curve in $n-1$ other points; then if p_1, p_2, &c., be the perpendiculars from A to the tangents to the curve at these points, and if π_1, π_2, &c., be the perpendiculars from another fixed point B to the same tangents, taken in the same order, then $\Sigma \frac{\pi_1}{p_1}$ is constant, and the polar line of the point B, with respect to the system of tangents, for a system of multiples proportional to $\frac{\pi_1}{p_1}$, $\frac{\pi_1}{p_2}$ &c., is a fixed line."

SECTION II.—*Surfaces.*

1. "If with respect to a point O a system of planes be reciprocated, then the polar plane of O, with respect to the system, will be reciprocated into a point which is the centre of mean position of the points which are the reciprocals of the given planes; and conversely, if a system of points in space be reciprocated with respect to a point O, then the centre of mean

position of the points will be reciprocated into a plane, which is the polar plane of the point O, with respect to the system of planes reciprocal to the given system of points."

Proof—

Take O for origin, and let the equations of the planes be

$$A_1x + B_1y + C_1z + D_1 = 0, \quad A_2x + B_2y + C_2z + D_2 = 0, \text{ \&c.},$$

then the equation of the polar plane is

$$x\Sigma\frac{A_1}{D_1} + y\Sigma\frac{B_1}{D_1} + z\Sigma\frac{C_1}{D_1} + n = 0,$$

n being the number of planes.

Now, if (x_1, y_1, z_1), (x_2, y_2, z_2), &c., be the co-ordinates of the points reciprocal to the given planes, and $(\bar{x}, \bar{y}, \bar{z})$ those of the point reciprocal to the polar plane, we have

$$x_1 = -\frac{A_1}{D_1}k^2, \quad y_1 = -\frac{B_1}{D_1}k^2, \quad z_1 = -\frac{C_1}{D_1}k^2,$$

$$x_2 = -\frac{A_2}{D_2}k^2, \quad y_2 = -\frac{B_2}{D_2}k^2, \quad z_2 = -\frac{C_2}{D_2}k^2,$$

and so on, k being the radius of reciprocation.

We have also

$$n\bar{x} = -k^2\Sigma\frac{A_1}{D_1}, \quad n\bar{y} = -k^2\Sigma\frac{B_1}{D_1}, \quad n\bar{z} = -k^2\Sigma\frac{C_1}{D_1}.$$

Hence,

$$n\bar{x} = \Sigma x_1, \quad n\bar{y} = \Sigma y_1, \quad n\bar{z} = \Sigma z_1,$$

and the theorem is proved.

More generally, if we take any other point P, of which the co-ordinates are (α, β, γ), then the polar plane of P, with respect to the given system of planes for a system of multiples m_1, m_2, &c., has for equation

$$\Sigma\frac{m_1(A_1x + B_1y + C_1z + D_1)}{D_1 - A_1\alpha - B_1\beta - C_1\gamma} = 0.$$

Denoting now by p_1, p_2, &c., the perpendiculars from P to the given planes, and by π_1, π_2, &c., the perpendiculars from O to the same planes,

taken in the same order; then, as before, reciprocating from O, we find for the co-ordinates of the point which is the reciprocal of the above plane,

$$x\Sigma\frac{m_1\pi_1}{p_1}=\Sigma\frac{m_1\pi_1}{p_1}x_1,\quad y\Sigma\frac{m_1\pi_1}{p_1}=\Sigma\frac{m_1\pi_1}{p_1}y_1,\quad z\Sigma\frac{m_1\pi_1}{p_1}=\Sigma\frac{m_1\pi_1}{p_1}z_1,$$

or the point is the centre of mean position of the points reciprocal to the given planes for a system of multiples $\frac{m_1\pi_1}{p_1}$, $\frac{m_2\pi_2}{p_2}$, &c.

2. If through a point O we draw any line to intersect a given surface of order n in points $P_1, P_2, \ldots P_n$, then the locus of a point P on this line taken so that $\frac{n}{OP}=\Sigma\frac{1}{OP_1}$ is a plane, viz., the polar plane of O with respect to the surface.

By taking three positions of the line through O, cutting the surface respectively in the systems of points P_1, P_2, &c., Q_1, Q_2, &c., R_1, R_2, &c., it is seen that the polar plane of O with respect to the surface is the same as its polar plane with respect to the system of planes (P_1, Q_1, R_1), (P_2, Q_2, R_2), &c.; and by letting the three positions of the line through O coincide, we see that the polar plane of O with respect to the surface is the same as the polar plane of O with respect to any system of tangent planes to the surface, at the points where any position of the line through O intersects it.

Hence, by reciprocation, we have—

"If any three systems of parallel tangent planes be drawn to a surface of class n, viz., ρ_1, ρ_2, &c.; σ_1, σ_2, &c.; τ_1, τ_2, &c., then the centre of mean position of the n points $(\rho_1\sigma_1\tau_1)$, $(\rho_2\sigma_2\tau_2)$, &c., is a fixed point."

Or more particularly—

"If to a surface of class n any system of parallel tangent planes be drawn, then the centre of mean position of their points of contact is a fixed point."

3. If now, in the first theorem of (2), the point O were situated on the surface, and if any line through it intersect the surface in $n-1$ other points, P_1, P_2, &c., then the locus of a point P on this line, so that $\frac{n-1}{OP}=\Sigma\frac{1}{OP_1}$, is

easily found to be the polar quadric of O with respect to the surface; and, as before, we can prove that the polar plane of O, with respect to the $n-1$ tangent planes to the surface, at the points P_1, P_2, &c., envelops this quadric.

Reciprocating—

"If to a surface of class n, which touches the plane at infinity, any system of $n-1$ parallel tangent planes be drawn, then the locus of the centre of mean position of their points of contact is a paraboloid."

4. In general we have—

"If through a point O, which is a multiple point of order m, on a surface of order n, any line be drawn to meet the surface in $n-m$ other points P_1, P_2, &c., then the polar plane of the point O, with respect to the tangent planes to the surface at P_1, P_2, &c., envelops a surface of order $m+1$, which also has O for a multiple point of order m."

Reciprocally—

"If a surface of class n touch the plane at infinity along a plane curve of class m, then the locus of the centre of mean position of the points of contact of any system of $n-m$ parallel tangent planes to the surface is a surface of class $m+1$, which also touches the plane at infinity along a plane curve of class m."

5. One case of the foregoing theorems is particularly worthy of notice.

"If through a point O, which is a parabolic point on a surface of order n, any line be drawn to meet the surface in $n-1$ other points, P_1, P_2, &c., then the polar plane of O, with respect to the system of tangent planes to the surface at P_1, P_2, &c., envelops a quadric cone, which is touched by the tangent plane to the surface at O."

If now we call a double point on a surface at which the two tangent planes coincide a "unode," and the tangent plane at such a point a "uniplane," see Salmon's *Geometry of Three Dimensions*, 4th ed., p. 489, we have, by reciprocation from the above, the following theorem:—

"If a surface of class n has the plane at infinity for a uniplane, then the locus of the centre of mean position of the points of contact of any system of $n-1$ parallel tangent planes to the surface is a plane parabola."

6. Suppose now the equation of a surface of order n to be written

$$ax^n + x^{n-1}(b + cy + dz) + \&c. \ldots = 0;$$

then if a variable line always moves parallel to the axis of x, the locus of the centre of mean position of the points in which it intersects the surface is easily found to be a plane, of which the equation is

$$nax + cy + dz + b = 0,$$

which may be called the diametral plane of the surface corresponding to the direction of the axis of x.

This is an extension (to surfaces) of Newton's theorem for a plane curve.

Reciprocating, we easily find, as in the case of the plane—

"If through a variable right line, which moves in a fixed plane Π, a system of n tangent planes be drawn to a surface of class n, then the polar plane of any point in the plane Π, with respect to this system of tangent planes, always passes through a fixed point Q."

If now, in the first theorem of this Article, we take three positions of the moving line, and then suppose them to coincide, we see that the diametral plane of the surface, for a given direction, is the same as that of the system of tangent planes to the surface at the points where any position of the variable line intersects it; hence, in the reciprocal theorem, if we join any position of the variable right line to the points of contact of the tangent planes to the surface through another position of the line, then the polar plane of any point in Π, with respect to this system of planes, will also pass through Q."

Let now the equation of the plane Π be

$$Ax + By + Cz = 0,$$

and let the co-ordinates of the points of contact of tangent planes to the surface, through one position of the variable right line, be $(x_1 y_1 z_1)$, $(x_2 y_2 z_2)$, &c., and let a second position of the right line be determined by two points situated in Π, and having for co-ordinates $(\alpha_1 \beta_1 \gamma_1)$, $(\alpha_2 \beta_2 \gamma_2)$; then the

equations of the planes joining this position of the line to the n points will be

$$\begin{vmatrix} x, & y, & z, & 1 \\ x_1, & y_1, & z_1, & 1 \\ \alpha_1, & \beta_1, & \gamma_1, & 1 \\ \alpha_2, & \beta_2, & \gamma_2, & 1 \end{vmatrix} = 0, \quad \begin{vmatrix} x, & y, & z, & 1 \\ x_2, & y_2, & z_2, & 1 \\ \alpha_1, & \beta_1, & \gamma_1, & 1 \\ \alpha_2, & \beta_2, & \gamma_2, & 1 \end{vmatrix} = 0, \text{ \&c.}$$

Now the equation of the polar plane of the origin, or any other point on the plane Π, with respect to this system of planes, is

$$x\Sigma\frac{L_1}{\Delta_1} + y\Sigma\frac{M_1}{\Delta_1} + z\Sigma\frac{N_1}{\Delta_1} - n = 0,$$

where

$$L_1 = \begin{vmatrix} y_1, & z_1, & 1 \\ \beta_1, & \gamma_1, & 1 \\ \beta_2, & \gamma_2, & 1 \end{vmatrix}, \quad M_1 = \begin{vmatrix} z_1, & x_1, & 1 \\ \gamma_1, & \alpha_1, & 1 \\ \gamma_2, & \alpha_2, & 1 \end{vmatrix}, \quad N_1 = \begin{vmatrix} x_1, & y_1, & 1 \\ \alpha_1, & \beta_1, & 1 \\ \alpha_2, & \beta_2, & 1 \end{vmatrix},$$

$$\Delta_1 = \begin{vmatrix} x_1, & y_1, & z_1 \\ \alpha_1, & \beta_1, & \gamma_1 \\ \alpha_2, & \beta_2, & \gamma_2 \end{vmatrix}.$$

Now, since

$$A\alpha_1 + B\beta_1 + C\gamma_1 = 0, \quad A\alpha_2 + B\beta_2 + C\gamma_2 = 0,$$

we have

$$\Delta_1 = \frac{\Pi_1}{\lambda} \text{ where } \Pi_1 = Ax_1 + By_1 + Cz_1,$$

and

$$\lambda = \frac{A}{\beta_1\gamma_2 - \gamma_1\beta_2} = \frac{B}{\gamma_1\alpha_2 - \alpha_1\gamma_2} = \frac{C}{\alpha_1\beta_2 - \alpha_2\beta_1};$$

hence the equation of the polar plane may be written

$$x\left\{(\gamma_1-\gamma_2)\Sigma\frac{y_1}{\Pi_1} - (\beta_1-\beta_2)\Sigma\frac{z_1}{\Pi_1}\right\} + y\left\{(\alpha_1-\alpha_2)\Sigma\frac{z_1}{\Pi_1} - (\gamma_1-\gamma_2)\Sigma\frac{x_1}{\Pi_1}\right\}$$

$$+ z\left\{(\beta_1-\beta_2)\Sigma\frac{x_1}{\Pi_1} - (\alpha_1-\alpha_2)\Sigma\frac{y_1}{\Pi_1}\right\} + \frac{1}{\lambda}\left\{(Ax+By+Cz)\Sigma\frac{1}{\Pi_1} - n\right\} = 0.$$

As $(\alpha_1 \beta_1 \gamma_1)$ and $(\alpha_2 \beta_2 \gamma_2)$ vary, we easily find that this plane always passes through a fixed point, the co-ordinates of which are,

$$x = \frac{\Sigma \frac{x_1}{\Pi_1}}{\Sigma \frac{1}{\Pi_1}}, \qquad y = \frac{\Sigma \frac{y_1}{\Pi_1}}{\Sigma \frac{1}{\Pi_1}}, \qquad z = \frac{\Sigma \frac{z_1}{\Pi_1}}{\Sigma \frac{1}{\Pi_1}},$$

which are therefore the co-ordinates of the point Q.

From these values of (x, y, z) we infer—

"If through a variable right line, which moves always in a fixed plane Π, a system of n tangent planes be drawn to a given surface of class n, and if we denote by $p_1, p_2, \ldots p_n$, the perpendiculars to the fixed plane from the points of contact of the tangent planes, then the centre of mean position of these points of contact, for a system of multiples proportional to $\frac{1}{p_1}, \frac{1}{p_2}$, &c., is a fixed point, and $\Sigma \frac{1}{p_1}$ is constant."

By reciprocation we have—

"If through a fixed point A any right line be drawn to meet a given surface of order n in points $P_1, P_2, \ldots P_n$; then if p_1, p_2, &c., be the perpendiculars from A to the tangent planes to the surface at these points, and if π_1, π_2, &c., be perpendiculars from another fixed point B to the tangent planes taken in the same order, $\Sigma \frac{\pi_1}{p_1}$ is constant, and the polar plane of the point B, with respect to the system of tangent planes, for a system of multiples proportional to $\frac{\pi_1}{p_1}, \frac{\pi_2}{p_2}$, &c., is a fixed plane."

Again, by reciprocation from an arbitrary point, we infer—

"If through a variable right line, which moves always in a fixed plane Π, a system of tangent planes be drawn to a given surface of class n, and if we denote by p_1, p_2, &c., the perpendiculars to Π from the points of contact of the tangent planes, and by π_1, π_2, &c., the perpendiculars from the same points, taken in the same order, to another fixed plane, then $\Sigma \frac{\pi_1}{p_1}$ is constant."

7. Returning now to the theorem proved at the commencement of Article 6, Sect. II., write the equation of the surface

$$ax^n + x^{n-1}(b + cy + dz) + x^{n-2}(e + fy + gz + Ay^2 + Byz + Cz^2) + \ldots = 0.$$

If now the direction of the axis of x determines on the surface a point at infinity, the coefficient x^n vanishes, and we find for the locus of the centre of mean position of the $n - 1$ finite points, in which any line parallel to the axis of x meets the surface, the quadric

$$(n-1)(b + cy + dz)x + Ay^2 + Byz + Cz^2 + fy + gz + e = 0,$$

on which also the axis of x determines a point at infinity.

We can prove then, as in the case of plane curves, the following theorems :—

"If through any right line in a fixed tangent plane Π, to a surface of class n, a system of $n - 1$ tangent planes, distinct from Π, be drawn to the surface; then the polar plane of any point in Π, with respect to this system of tangent planes, envelops a quadric U, which also touches Π."

In the same case, if we denote by p_1, p_2, &c., the perpendiculars on the fixed tangent plane, from the points of contact of the other $n - 1$ tangent planes; then the locus of the centre of mean position of these points of contact, for a system of multiples proportional to $\frac{1}{p_1}, \frac{1}{p_2}$, &c., is the quadric U."

By reciprocation—

"If through a point A, situated on a surface of order n, any line be drawn to meet the surface in $n - 1$ points distinct from A, and if we denote by p_1, p_2, &c., the perpendiculars from A to the tangent planes to the surface at these points, and by π_1, π_2, &c., the perpendiculars from another fixed point B to the same planes, taken in the same order; then the polar plane of B, with respect to this system of tangent planes, for a system of multiples proportional to $\frac{\pi_1}{p_1}, \frac{\pi_2}{p_2}$, &c., envelops a quadric which passes through A."

8. If in the first theorem of Art. 7 the direction of the axis of x determines on the surface a parabolic point at infinity, the quadric locus of the theorem becomes a cone passing through that point, and we infer the following theorem :—

"If through any right line in a plane Π, which is a uniplane to a surface of class n, a system of $n-1$ tangent planes, distinct from Π, be drawn to the surface; then the locus of the centre of mean position of the points of contact of these tangent planes, for a system of multiples proportional to the reciprocals of the perpendiculars from these points on Π, is a plane conic, which is touched by the trace of its plane on Π."

END OF VOLUME XXVIII.—SCIENCE.

DUBLIN:
Printed at the University Press, by PONSONBY AND WELDRICK, Printers to the Royal Irish Academy.

[DECEMBER, 1880.]

THE

TRANSACTIONS

OF THE

ROYAL IRISH ACADEMY.

VOLUME XXVIII.

SCIENCE.

I.—*On Chemical Equilibrium.* By FRANCIS ALEXANDER TARLETON, LL.D., Fellow and Tutor, Trinity College, Dublin.

DUBLIN:
PUBLISHED BY THE ACADEMY,
AT THE ACADEMY HOUSE, 19, DAWSON-STREET.
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